

CMB Constraints on Dark Matter Annihilation

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Stony Brook University

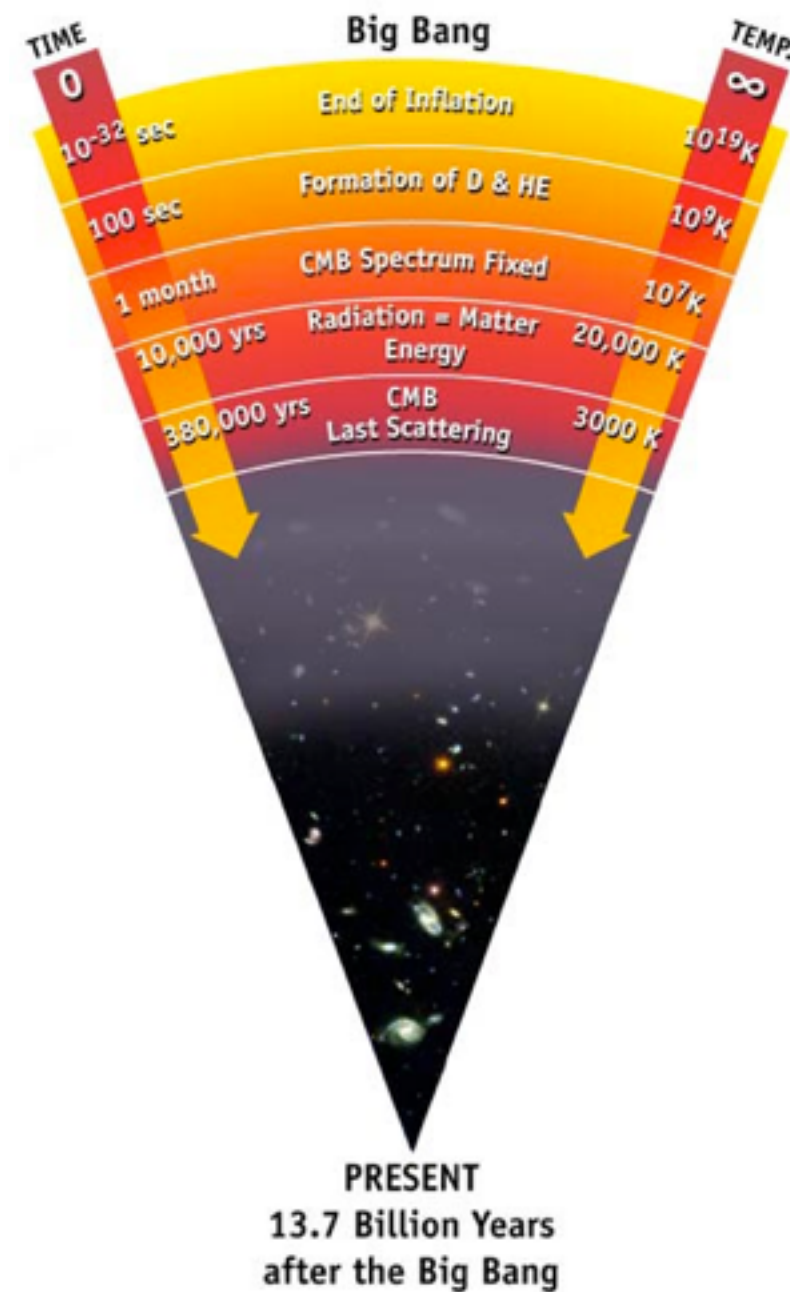
Outline

- The CMB in a Nutshell
- Current Dark Matter Annihilation Bounds from the CMB

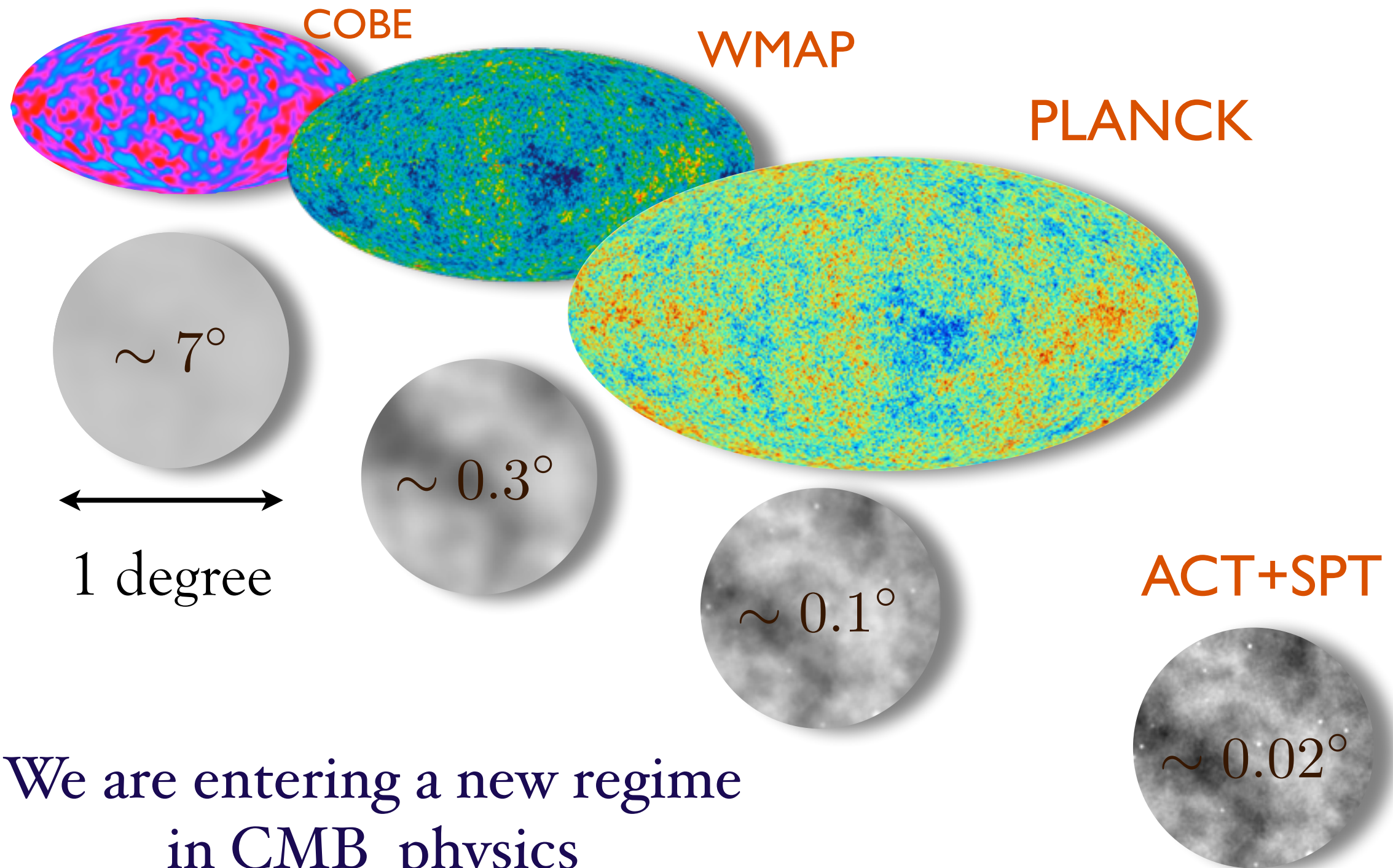
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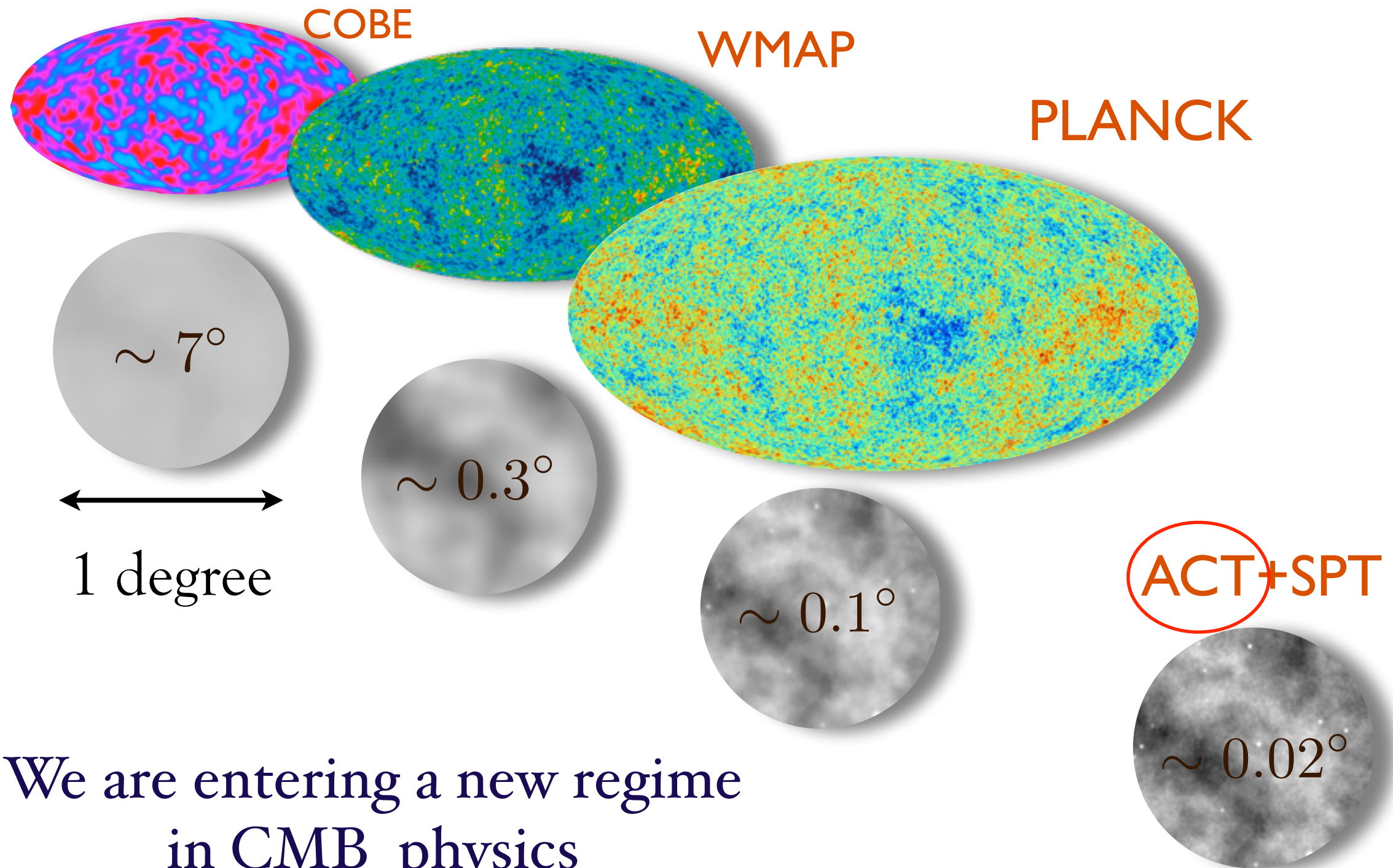
Cosmic Microwave Background



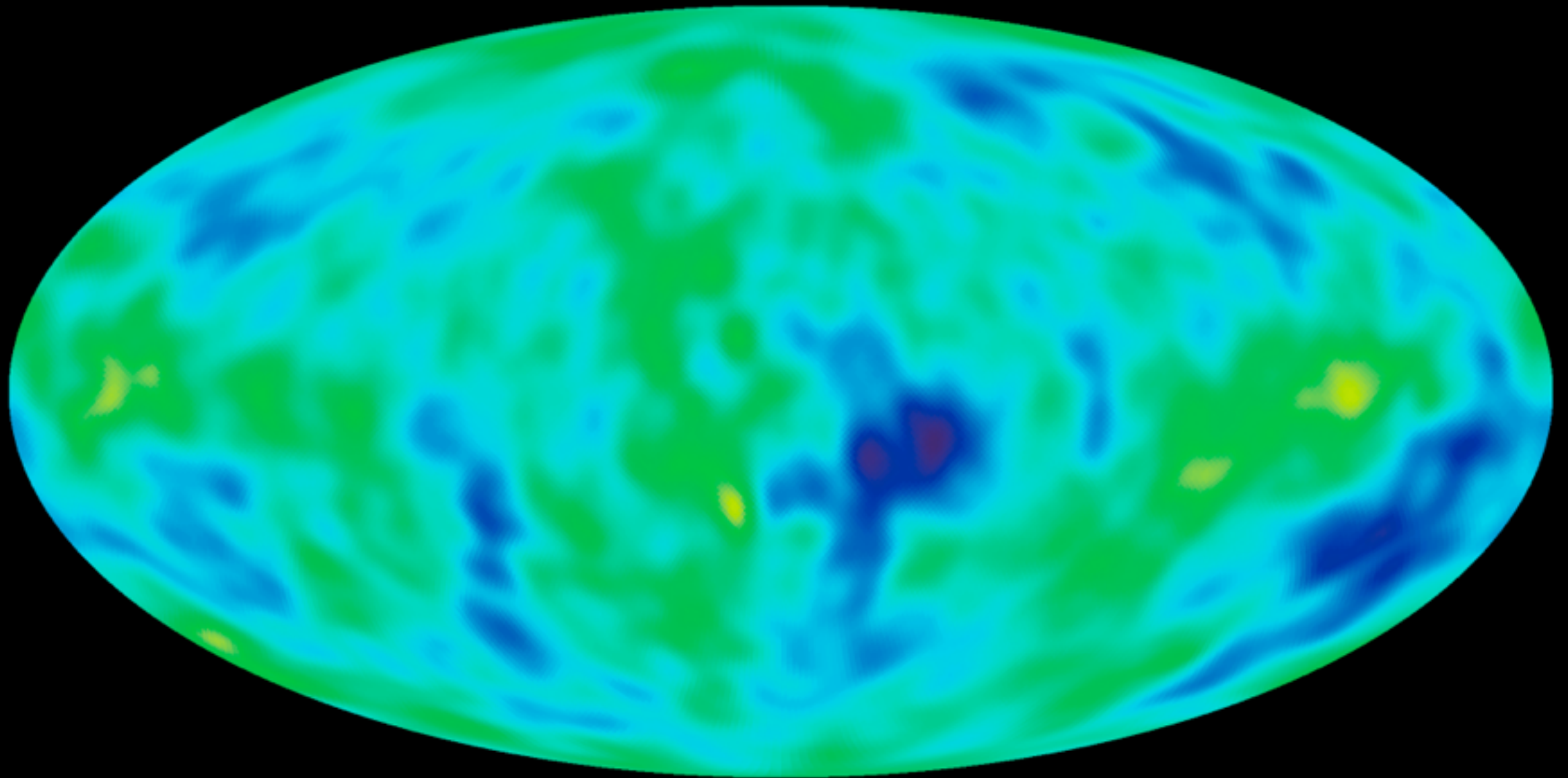
New Generation of Microwave Observations



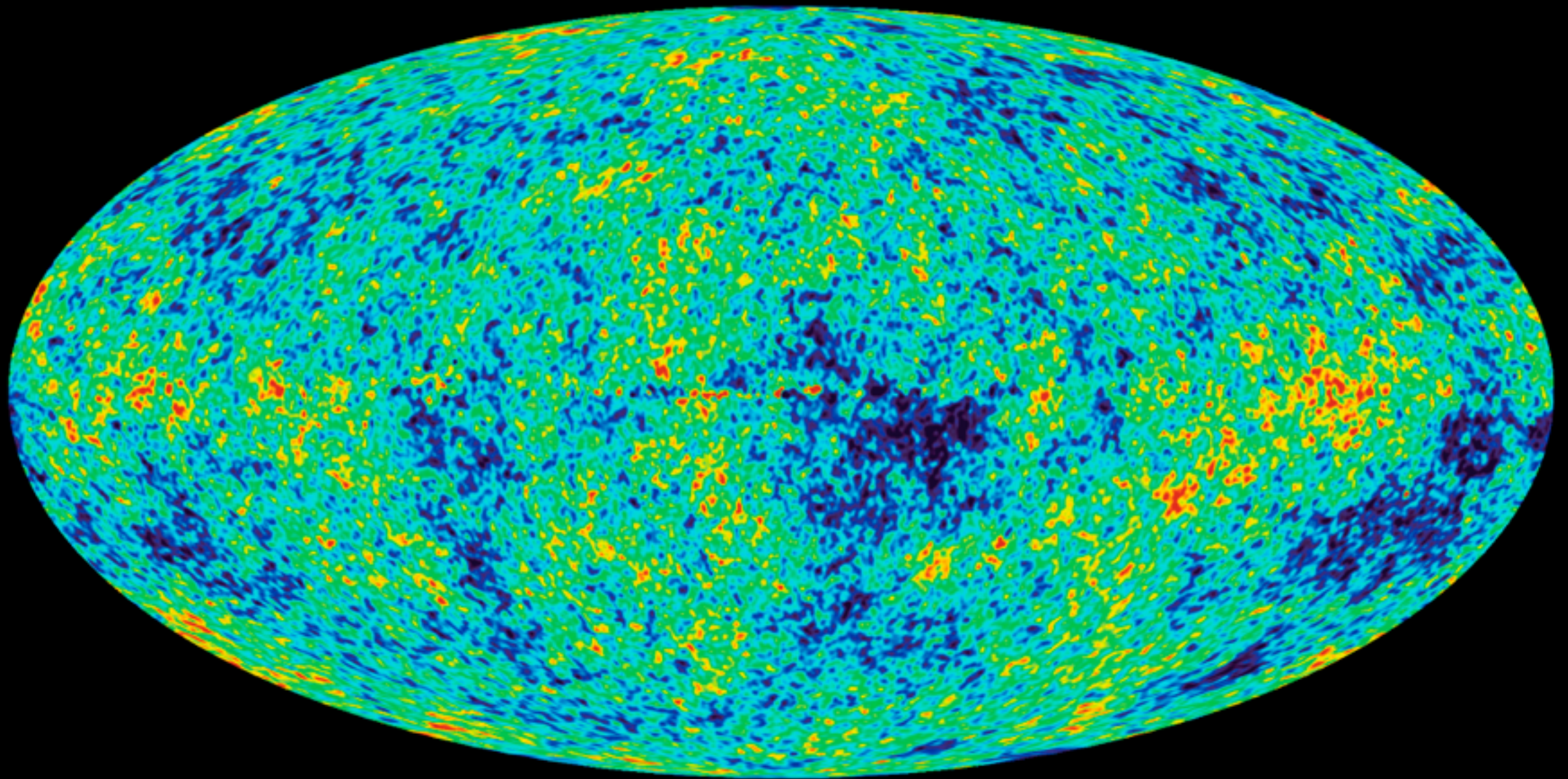
New Generation of Microwave Observations



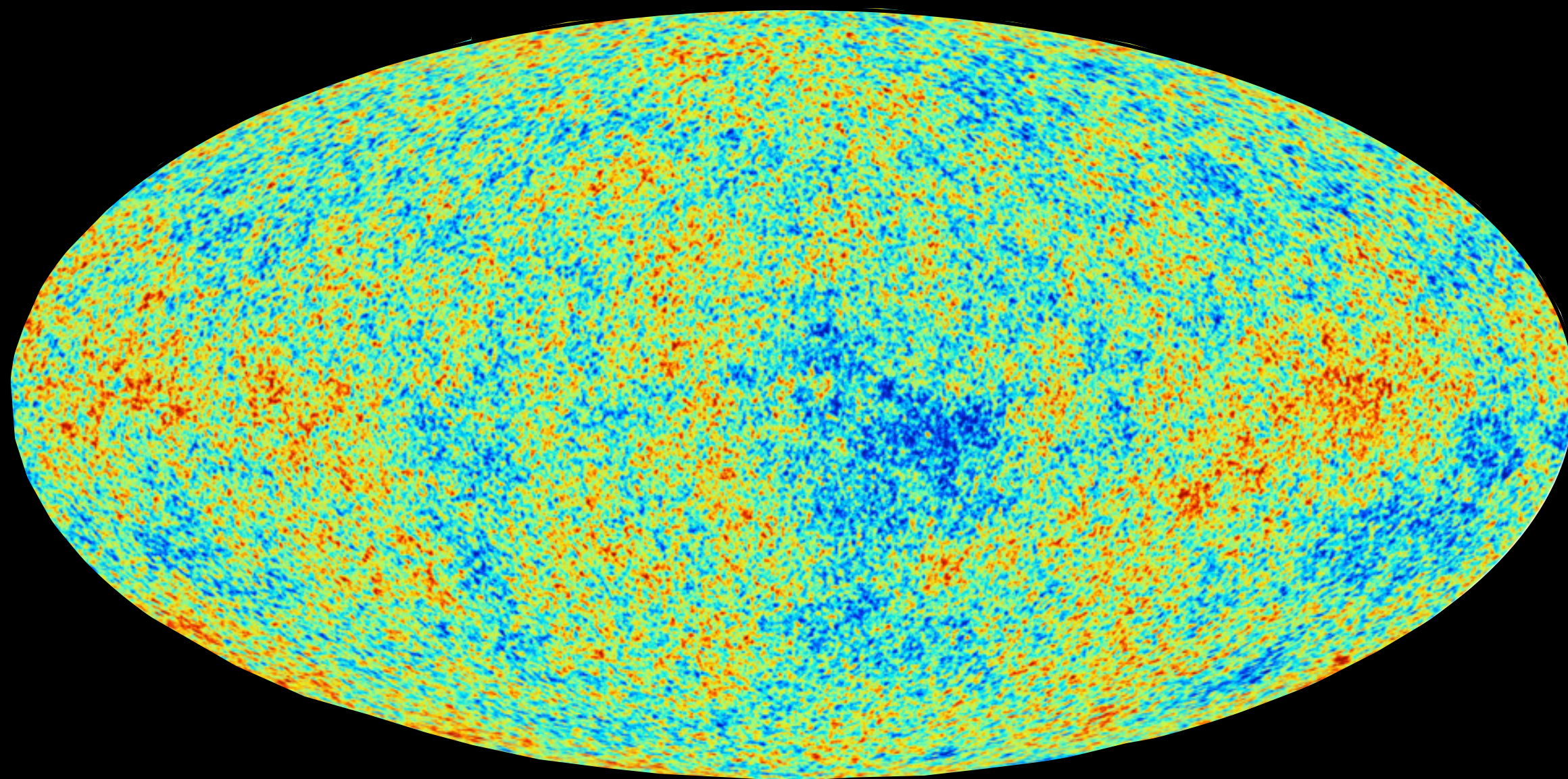
COBE Satellite 1994



WMAP Satellite 2003



Planck Satellite 2013

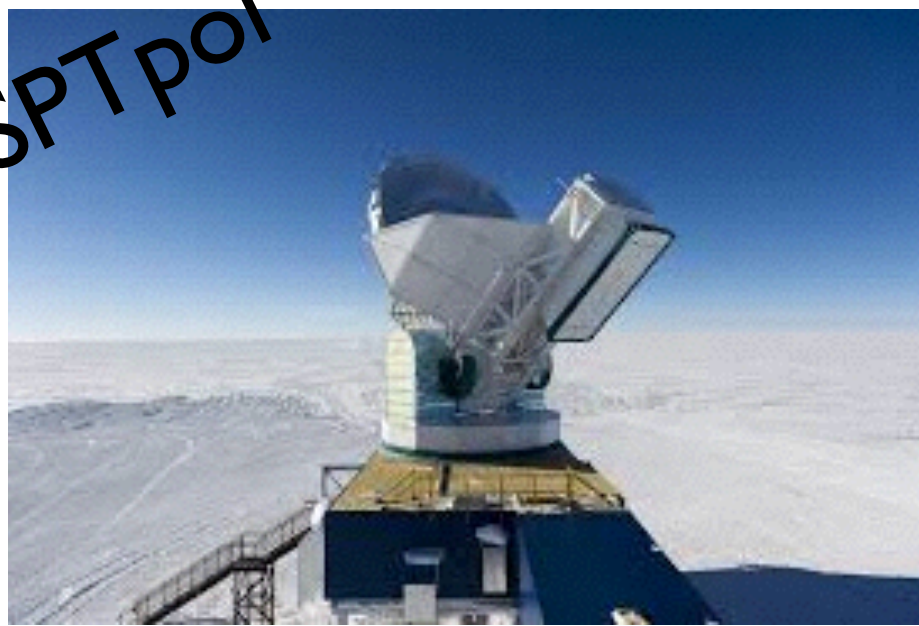


Other CMB Experiments

ACTpol

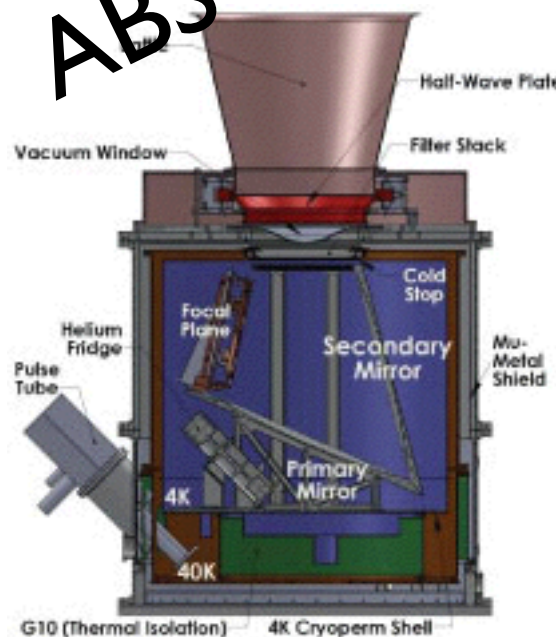


SPTpol



➔ Have broad science range

ABS



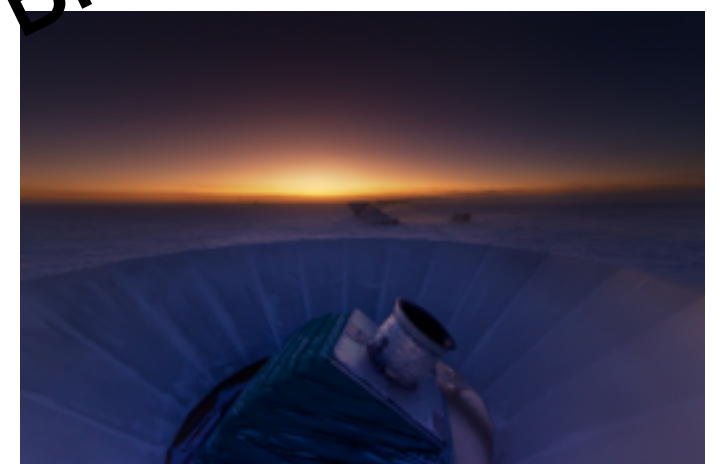
Polarbear



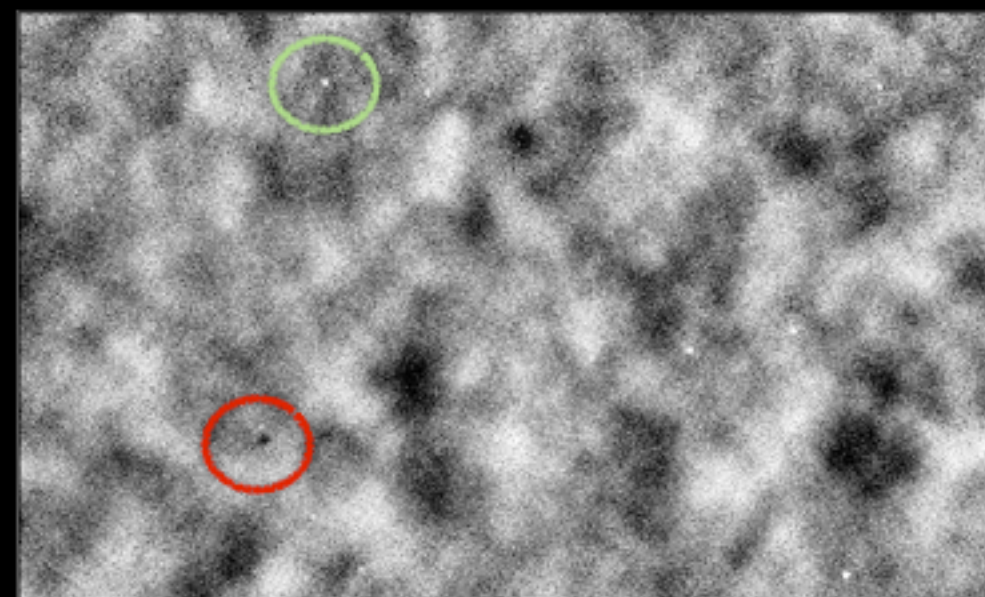
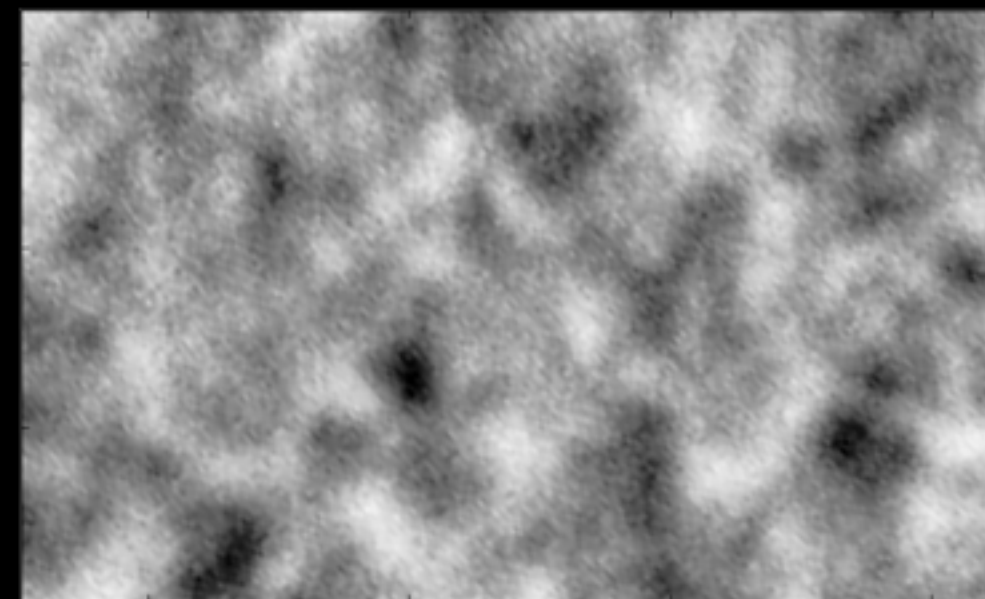
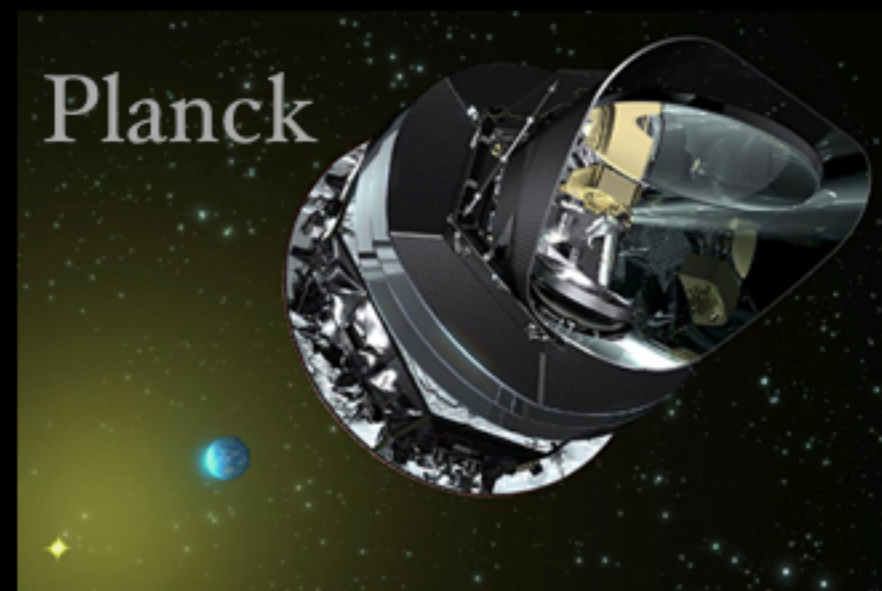
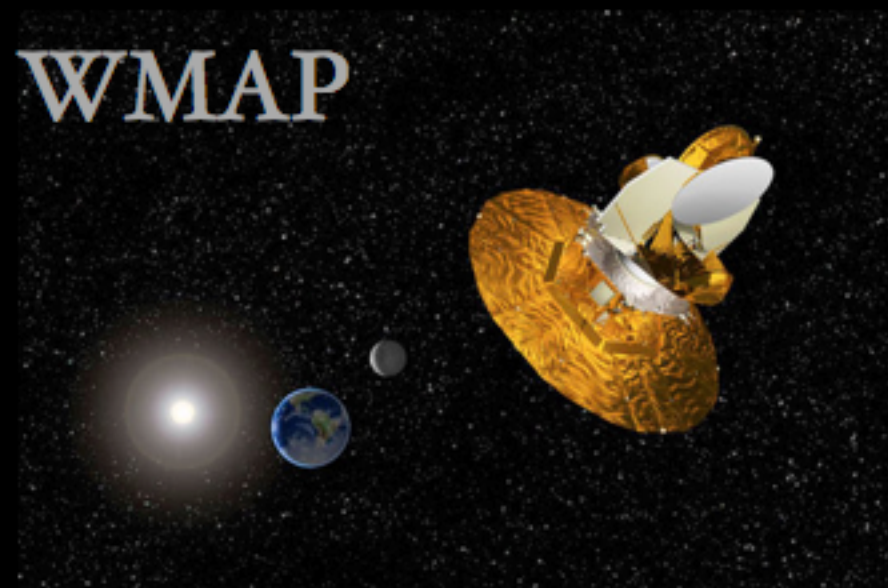
SPIDER



BICEP



➔ Dedicated to r



Amir Hajian for ACT

ACTpol / AdvACTpol

ACTpol - Observes from 2013 - 2015

~4000 sq deg (10% of sky)

4 x better sensitivity than Planck

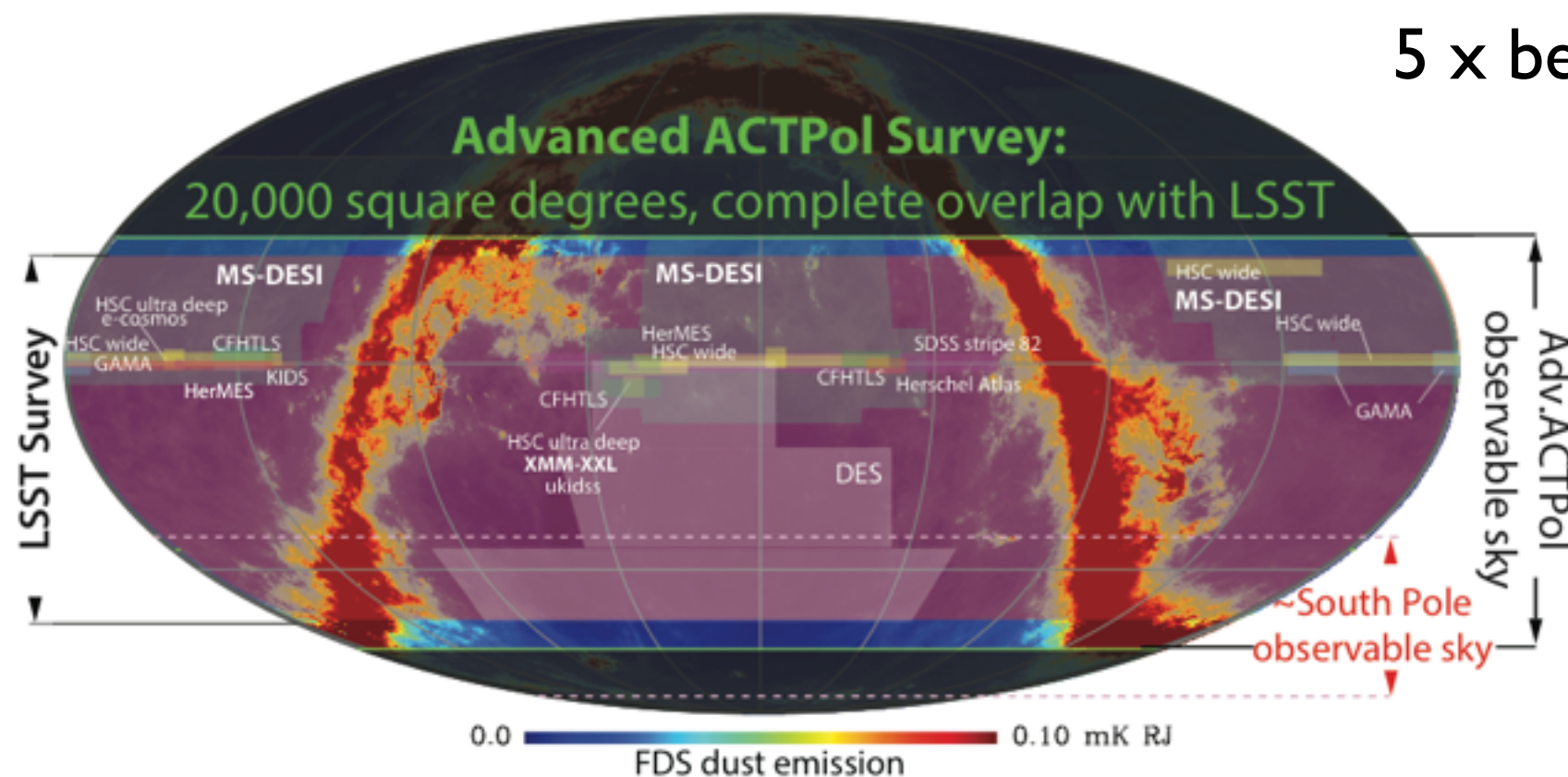
5 x better resolution than Planck

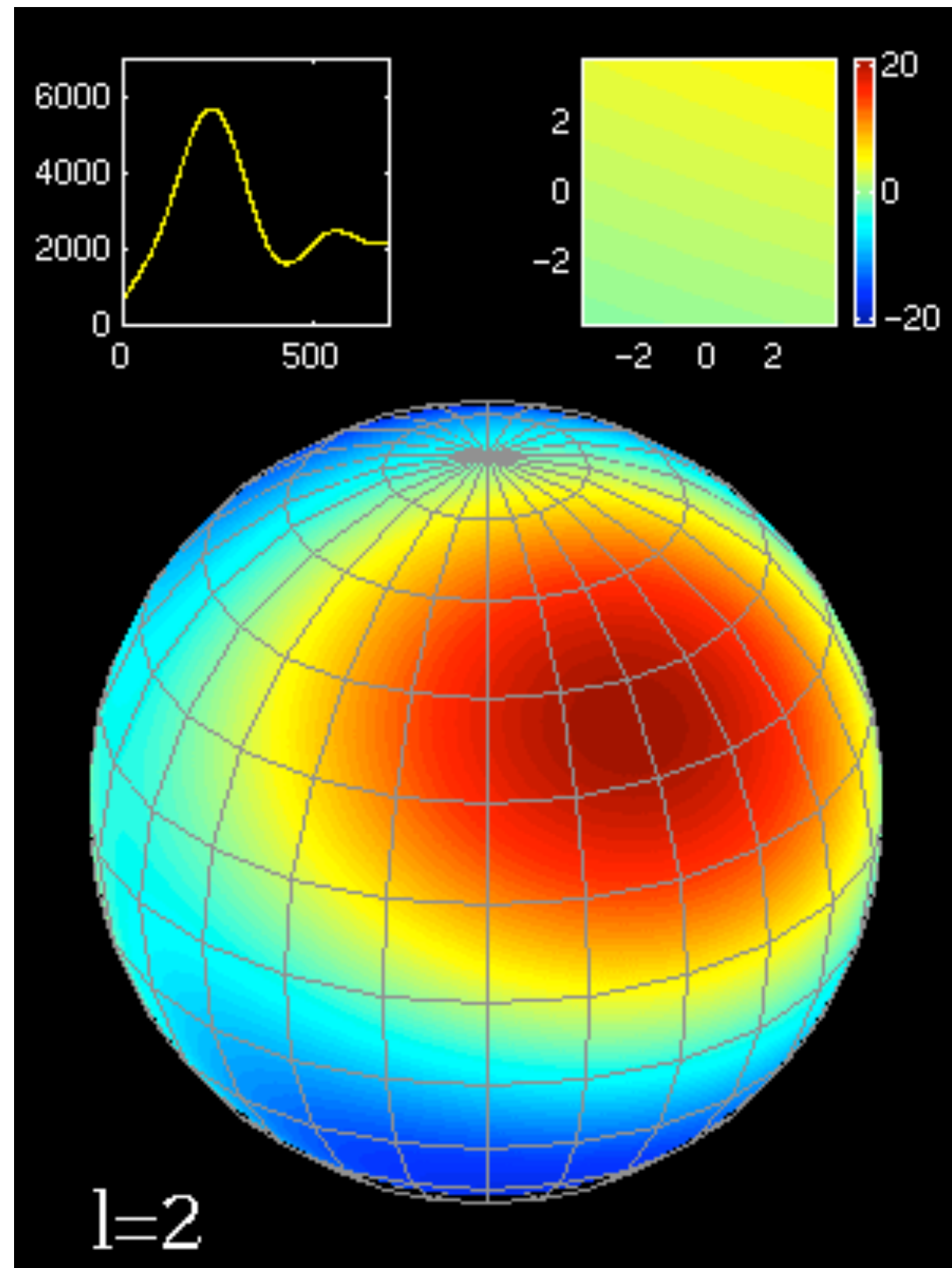
AdvACTpol - 2015 - 2017

~20,000 sq deg (50% of sky)

4 x better sensitivity than Planck

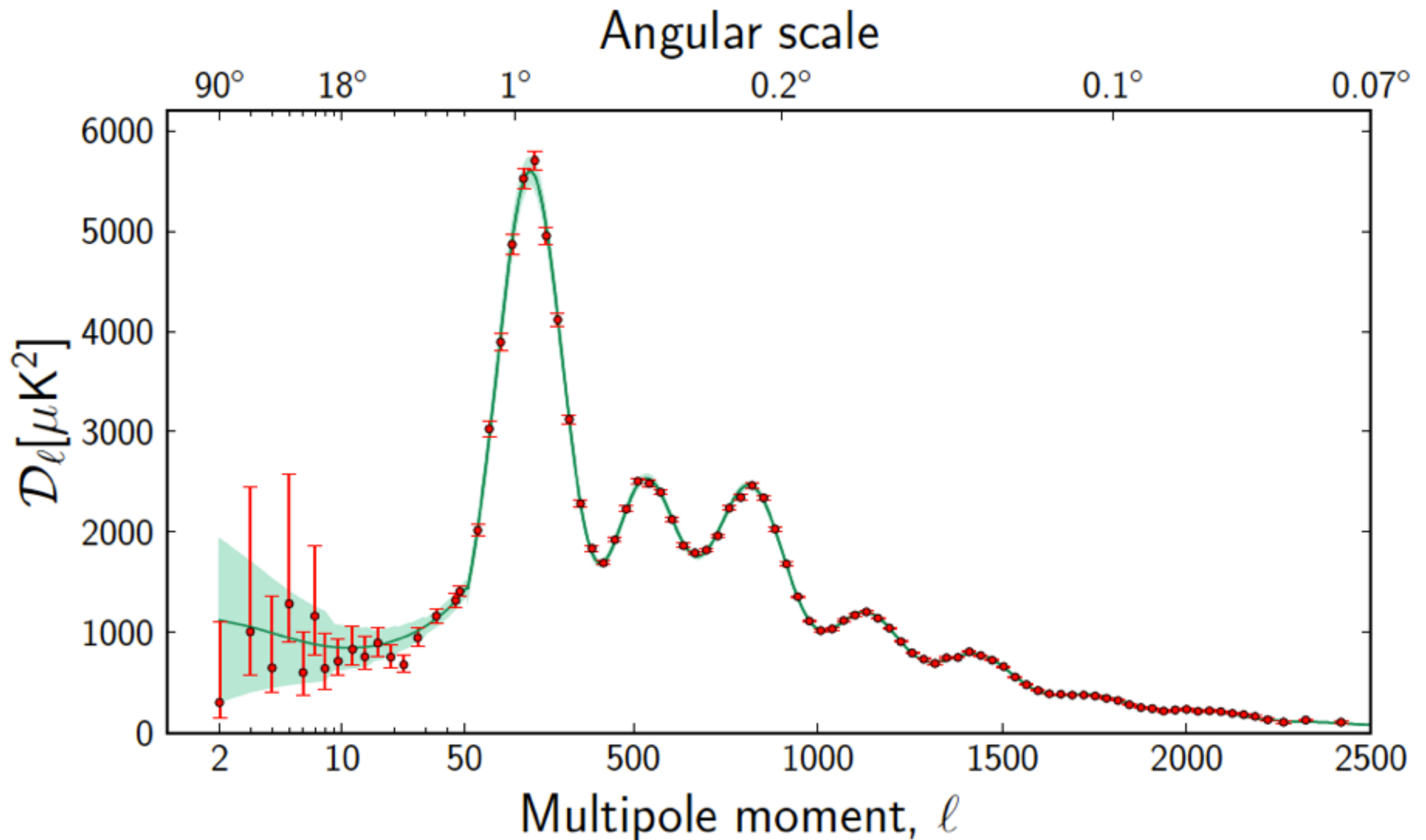
5 x better resolution than Planck



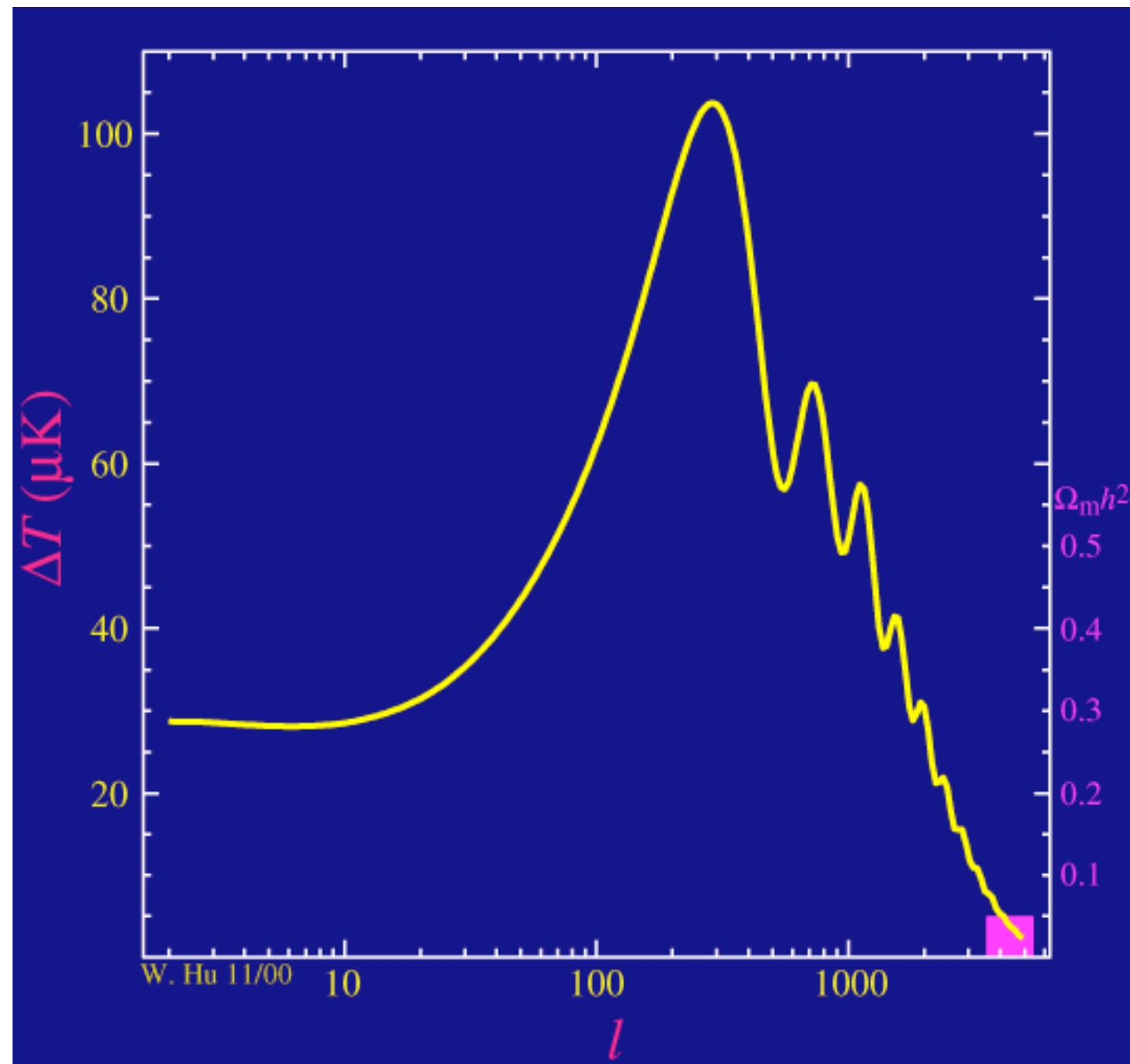


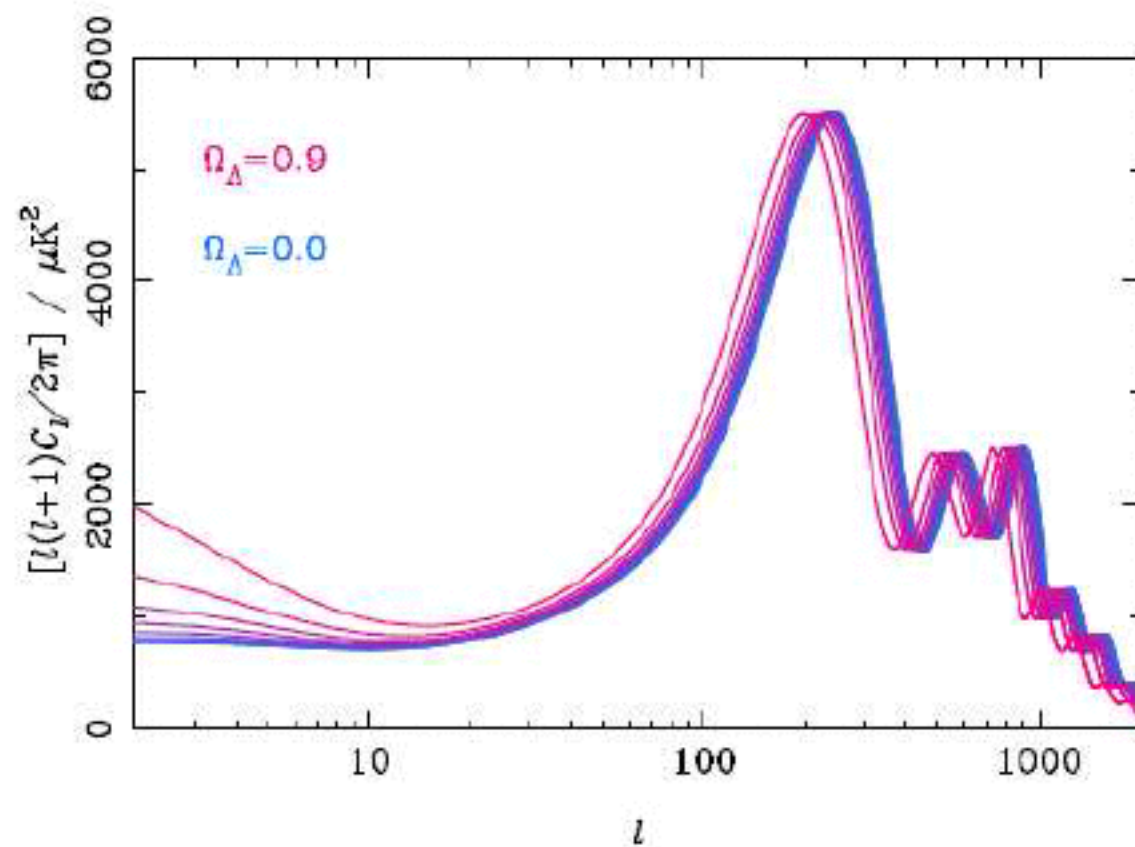
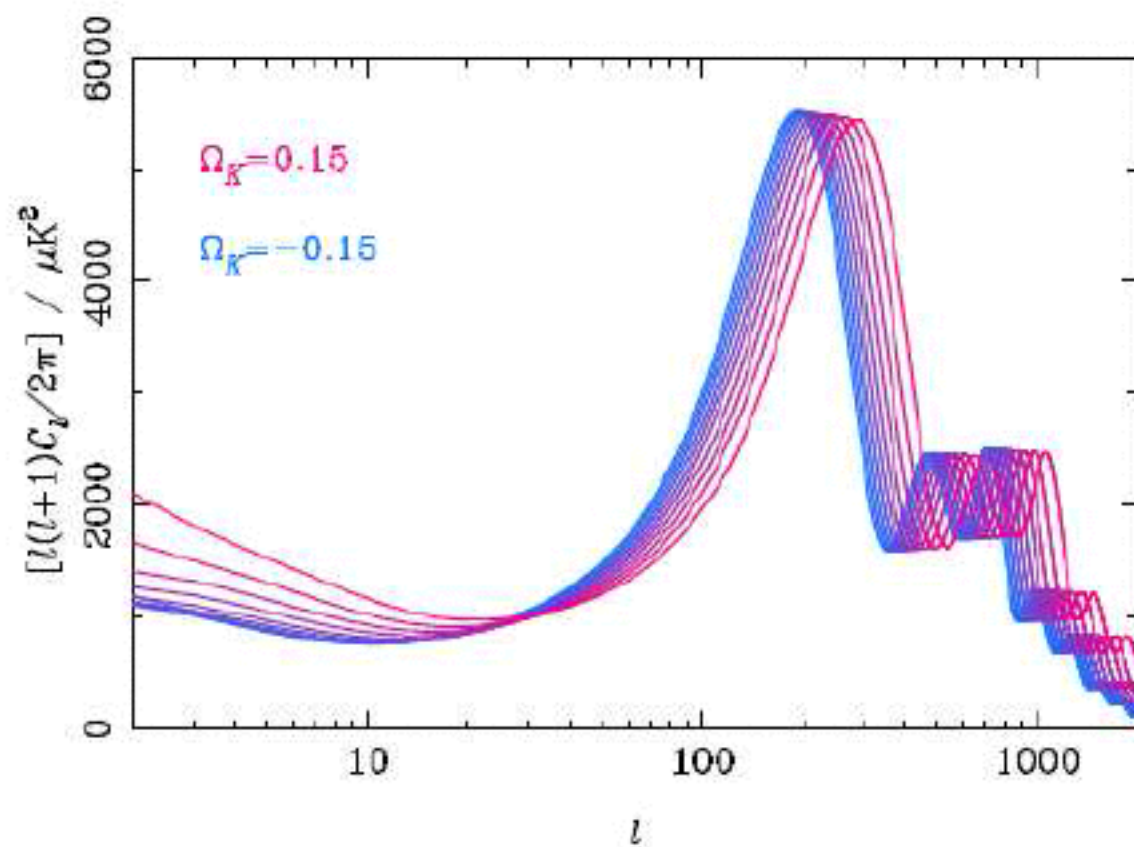
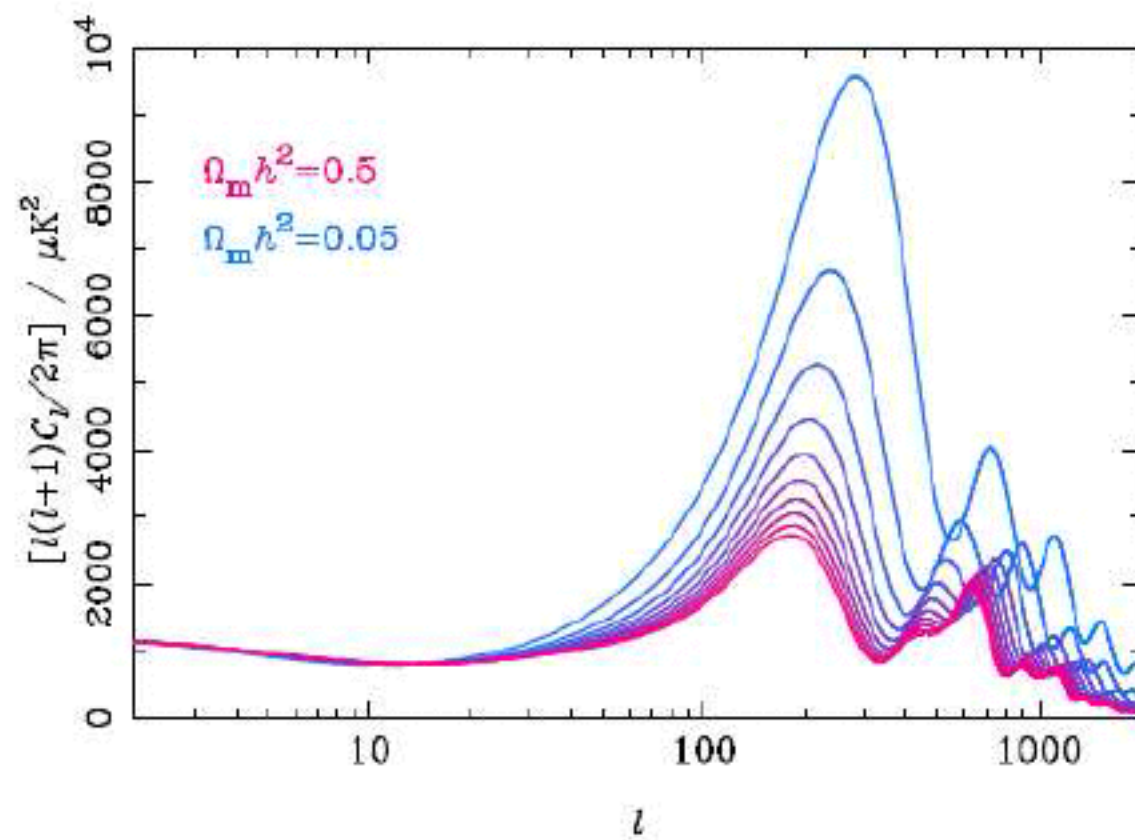
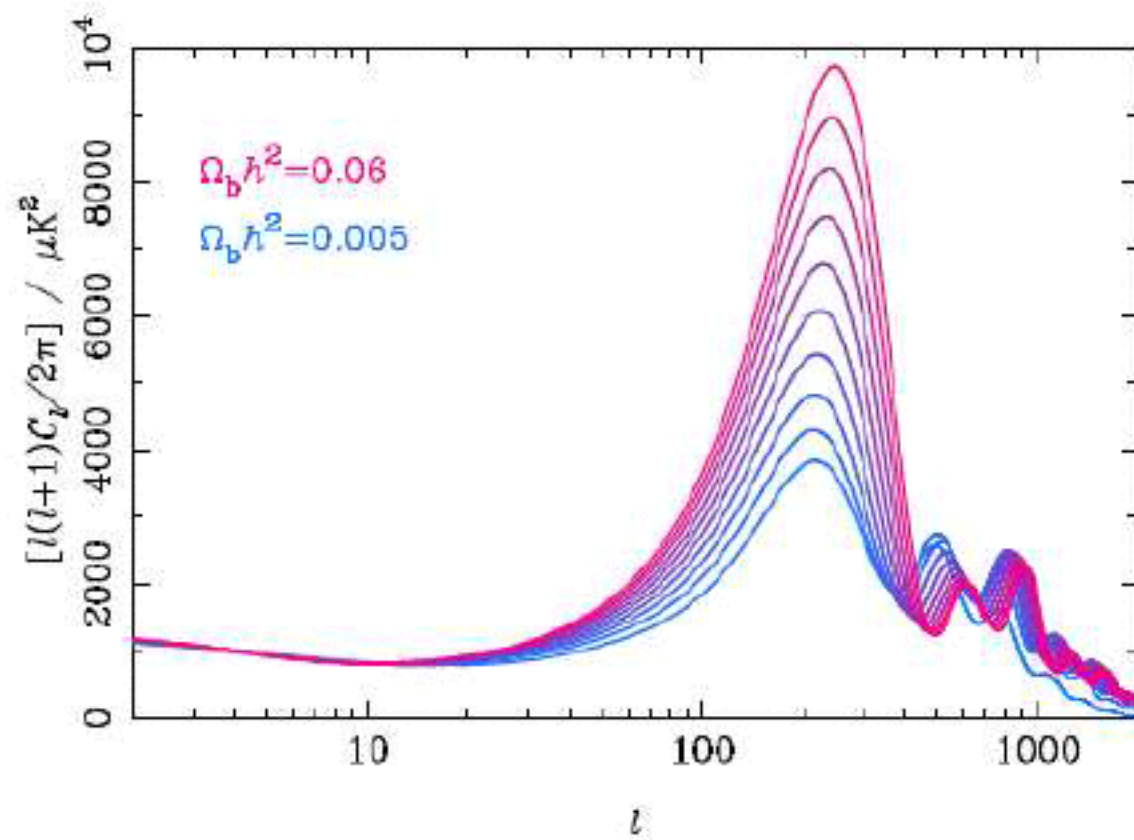
Made by Clem Pryke

Planck Power Spectrum



Parameters Change CMB Power

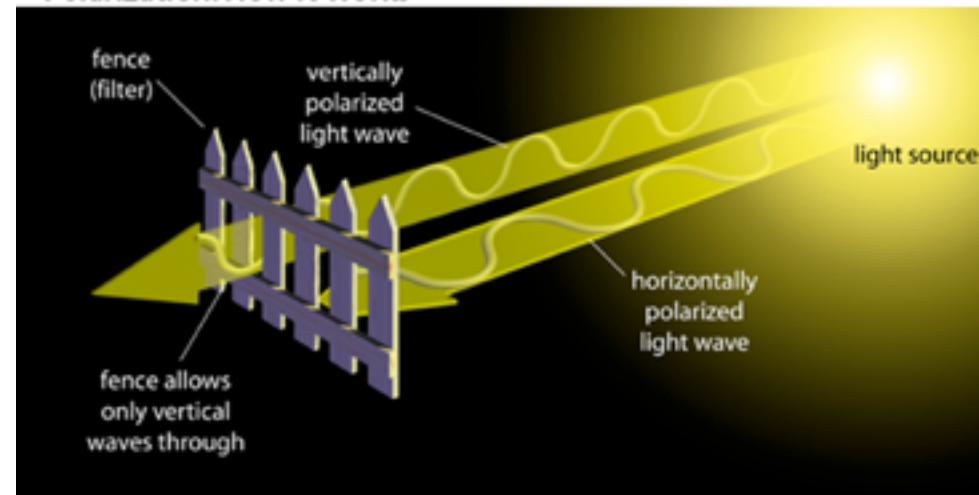




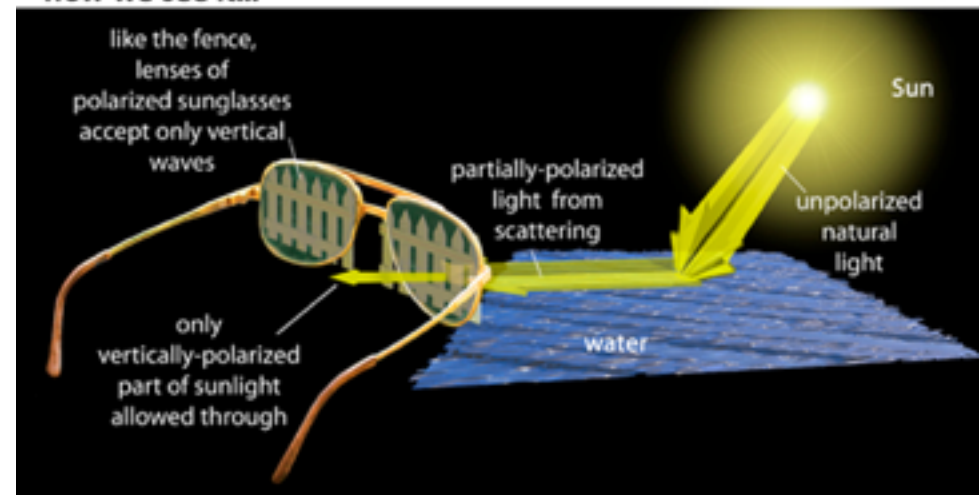
Credit: Anthony Challinor

CMB Polarization

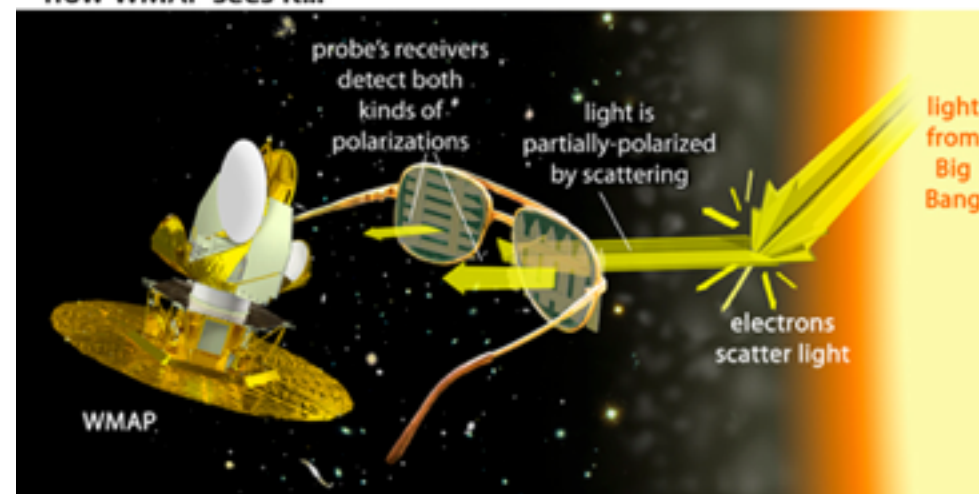
Polarization: How It Works



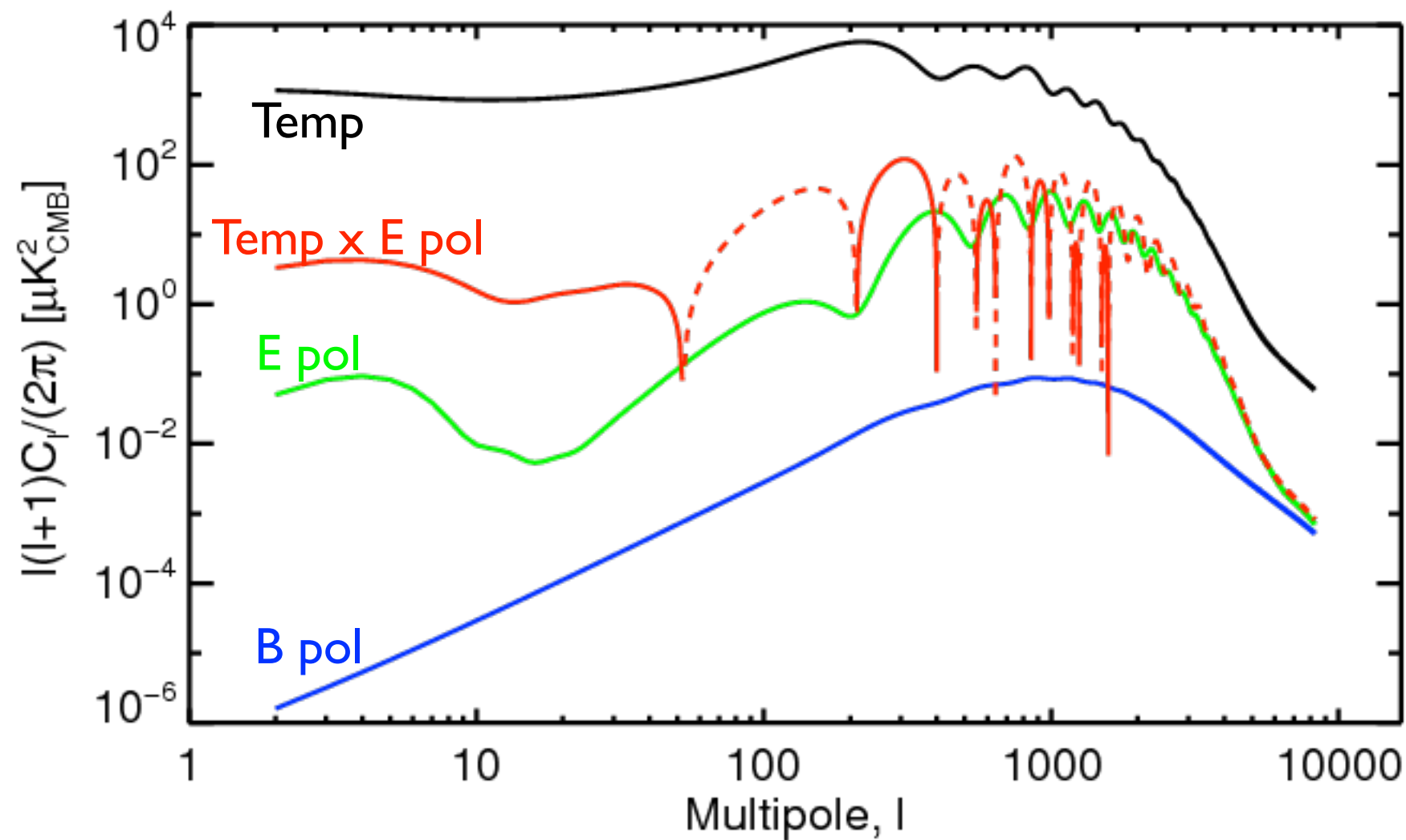
how we see it...



how WMAP sees it...

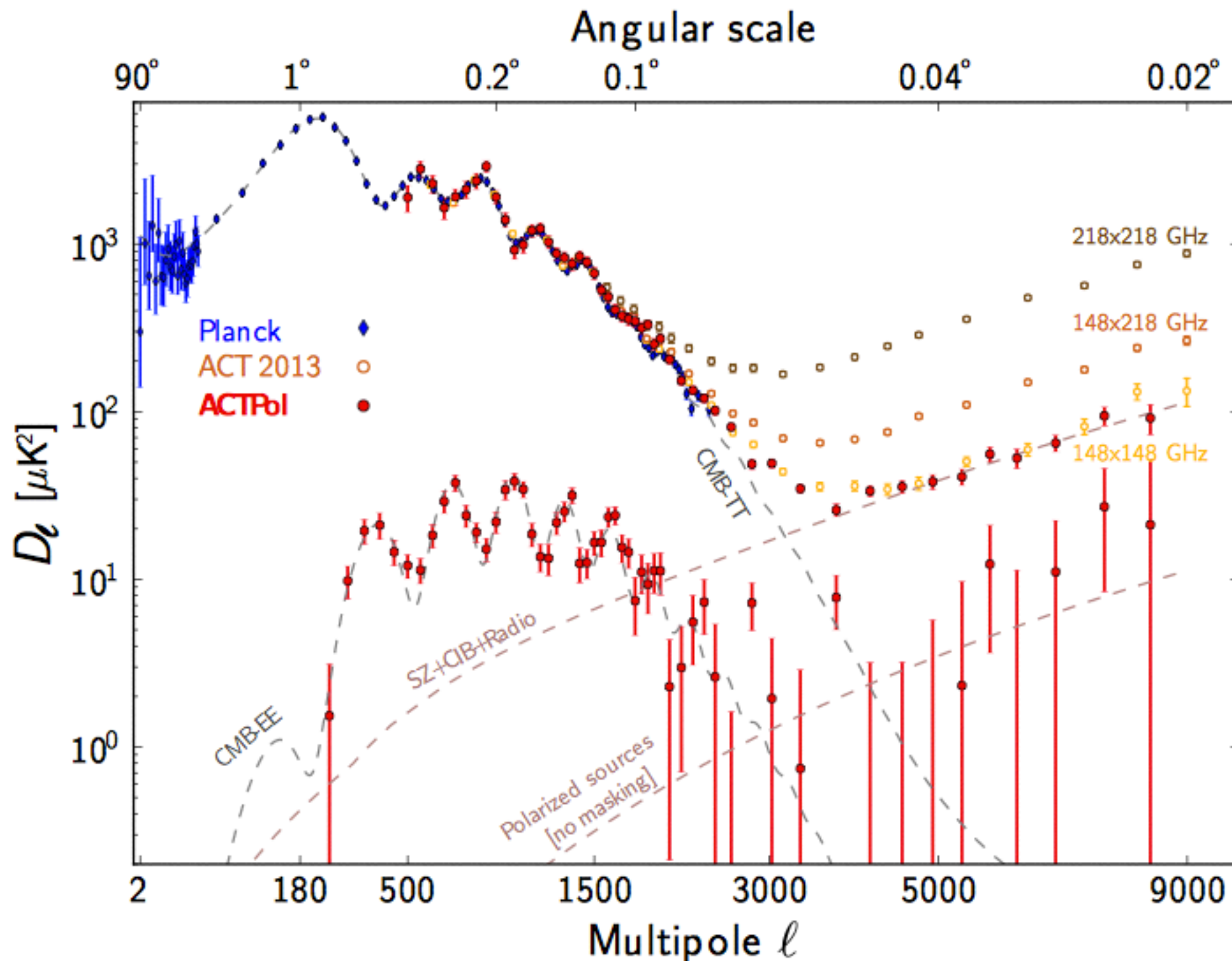


CMB Polarization



First Results from ACTpol

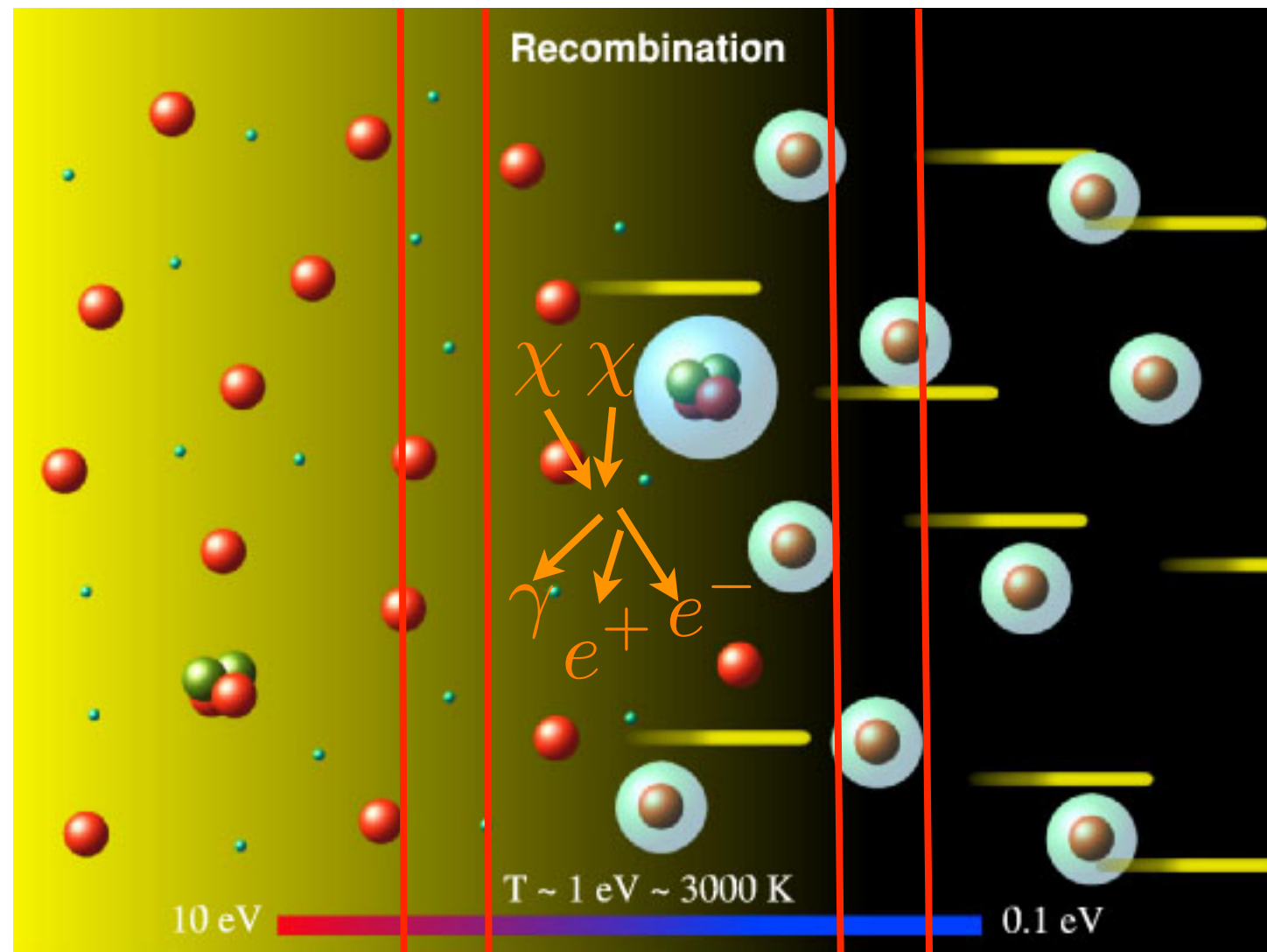
Best High- ℓ EE Power Spectrum Measured to Date!



Outline

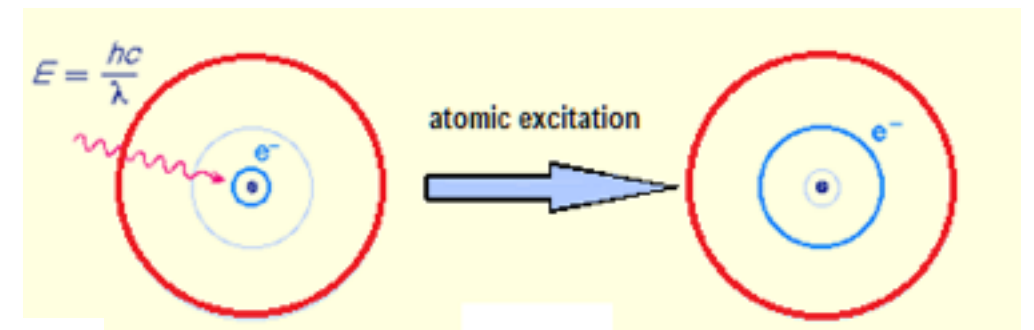
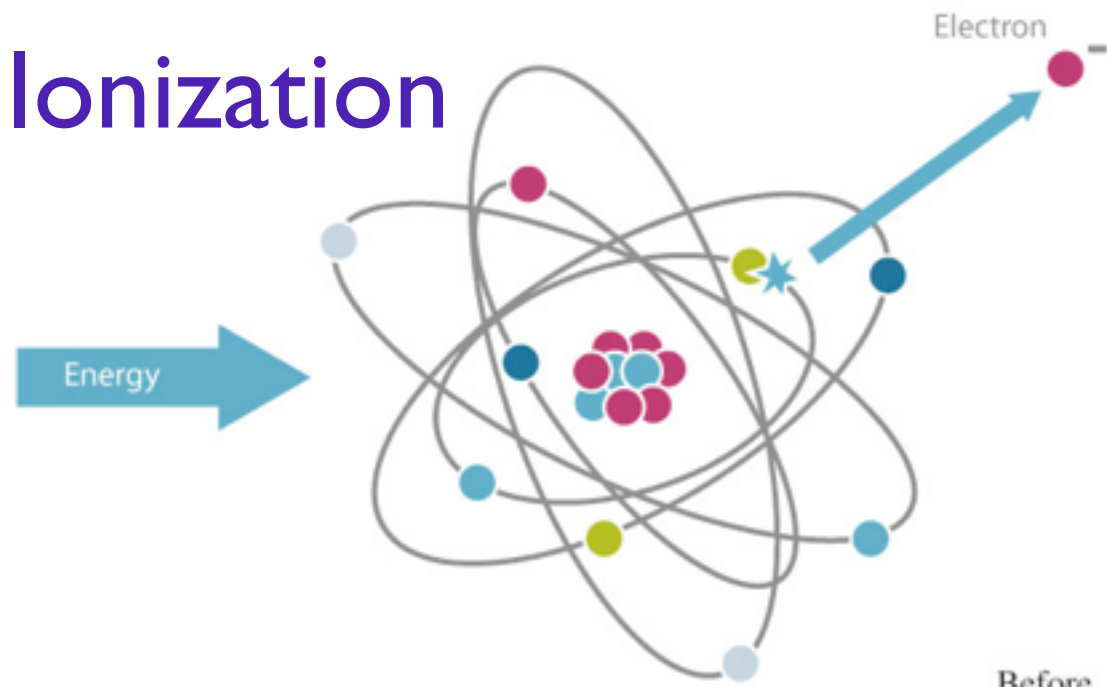
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Dark Matter Annihilation During Recombination

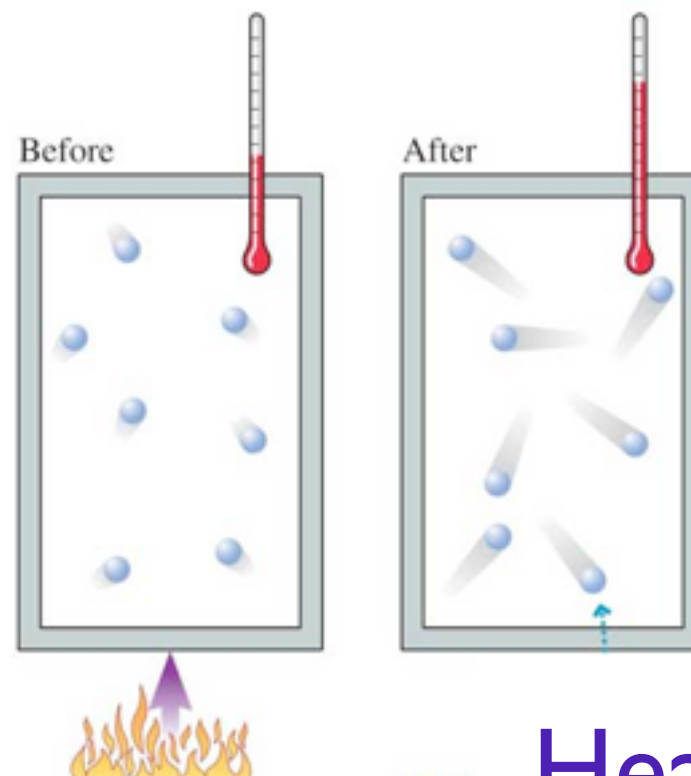


Energy Deposition in Pre- and Post-Recombination Gas/Plasma

Ionization

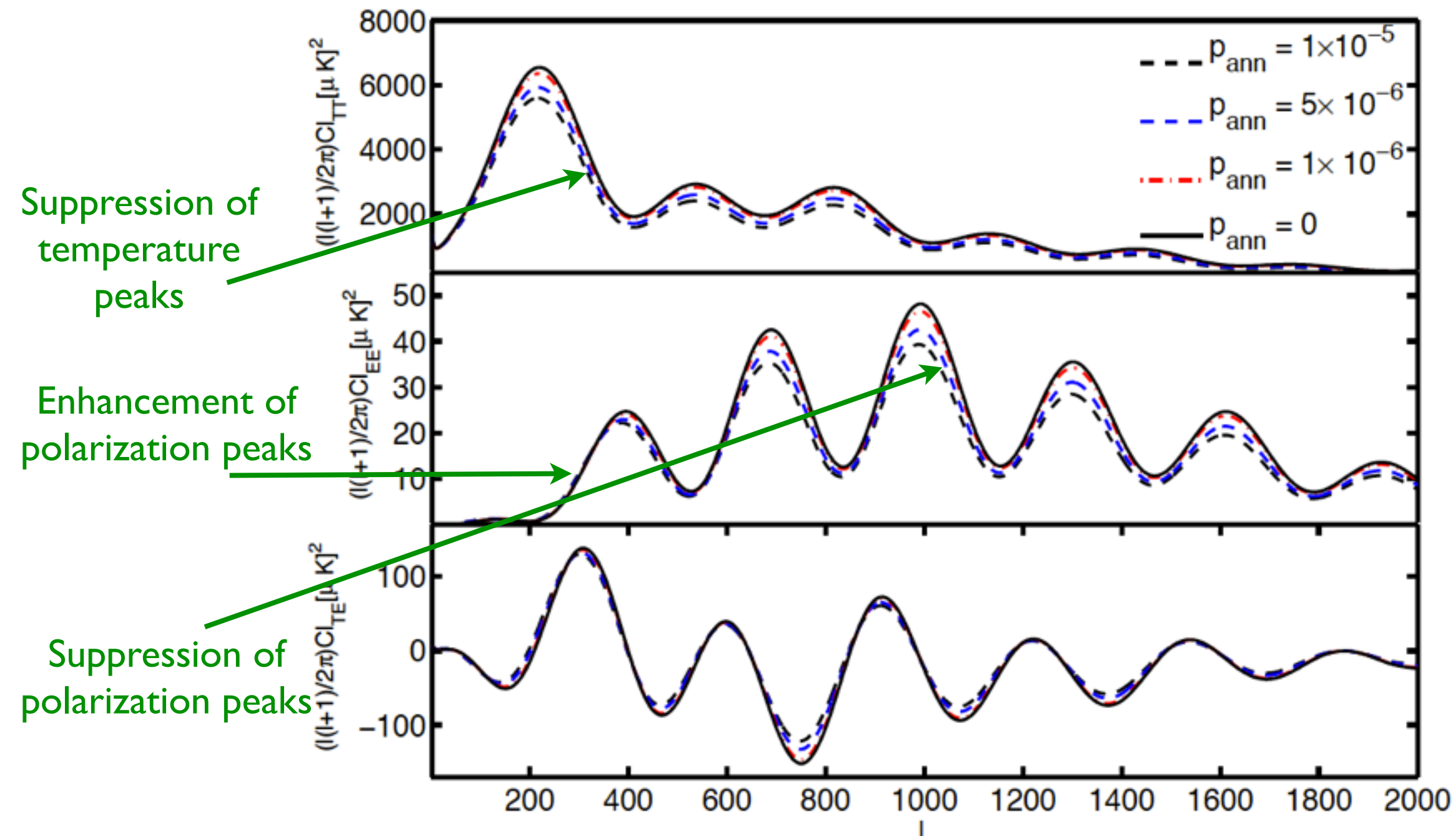


Excitation

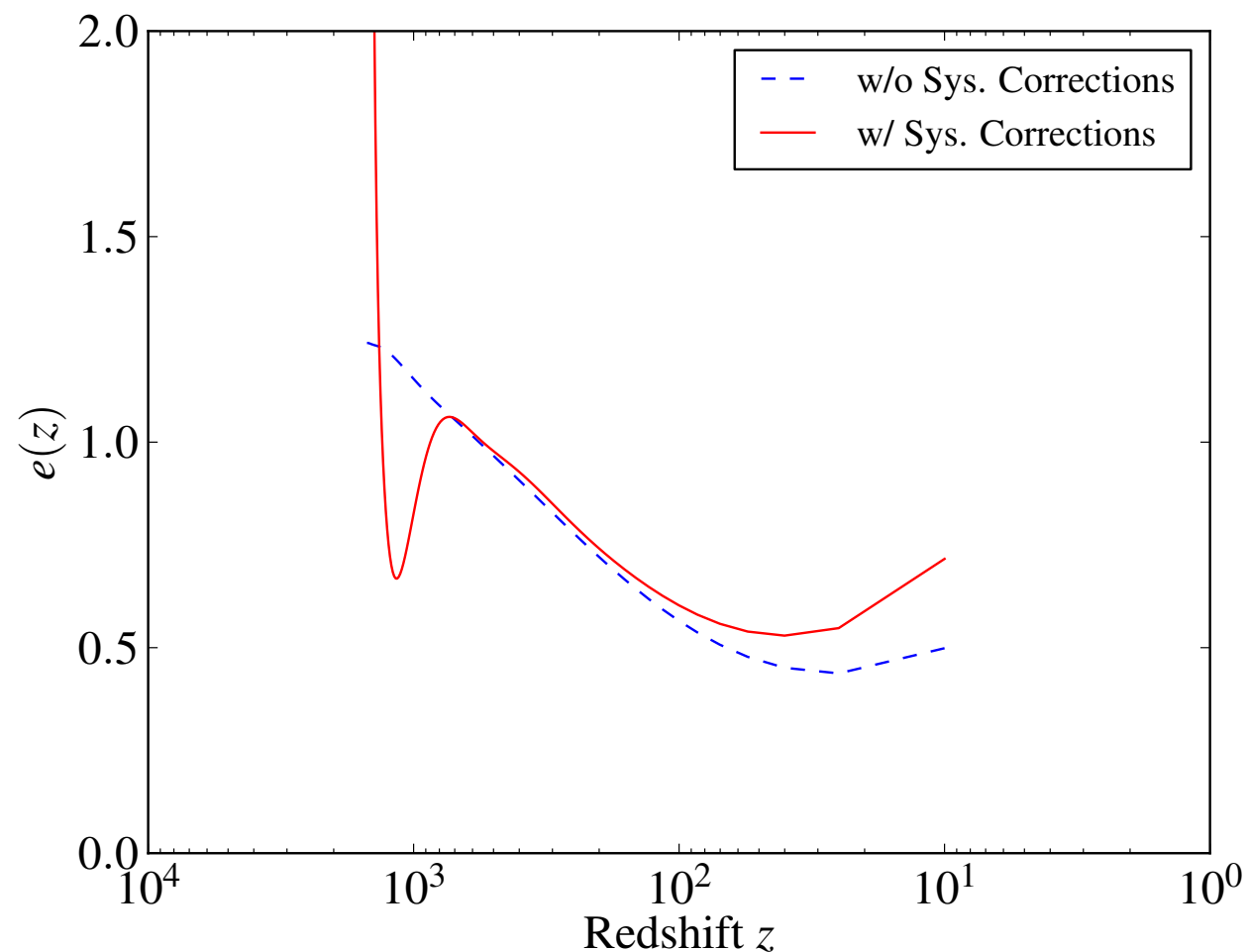


Heating

Effect of Dark Matter Annihilation on CMB



Universal Energy Deposition Curve



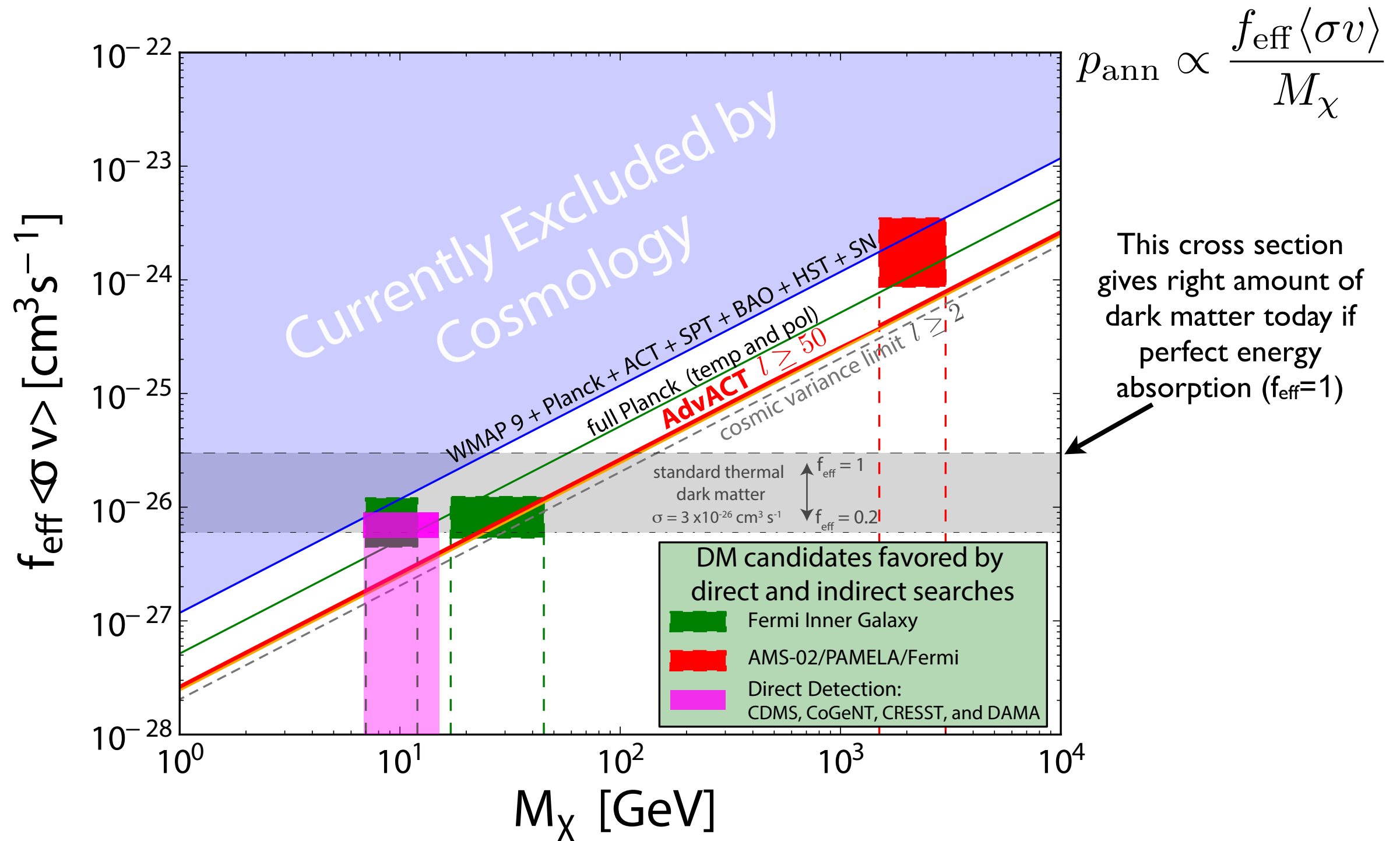
$$f(z) = \sum_{i=1}^{41} \alpha_i f_i(z)$$

$$f(z) = \sum_{i=1}^{41} \beta_i e_i(z)$$

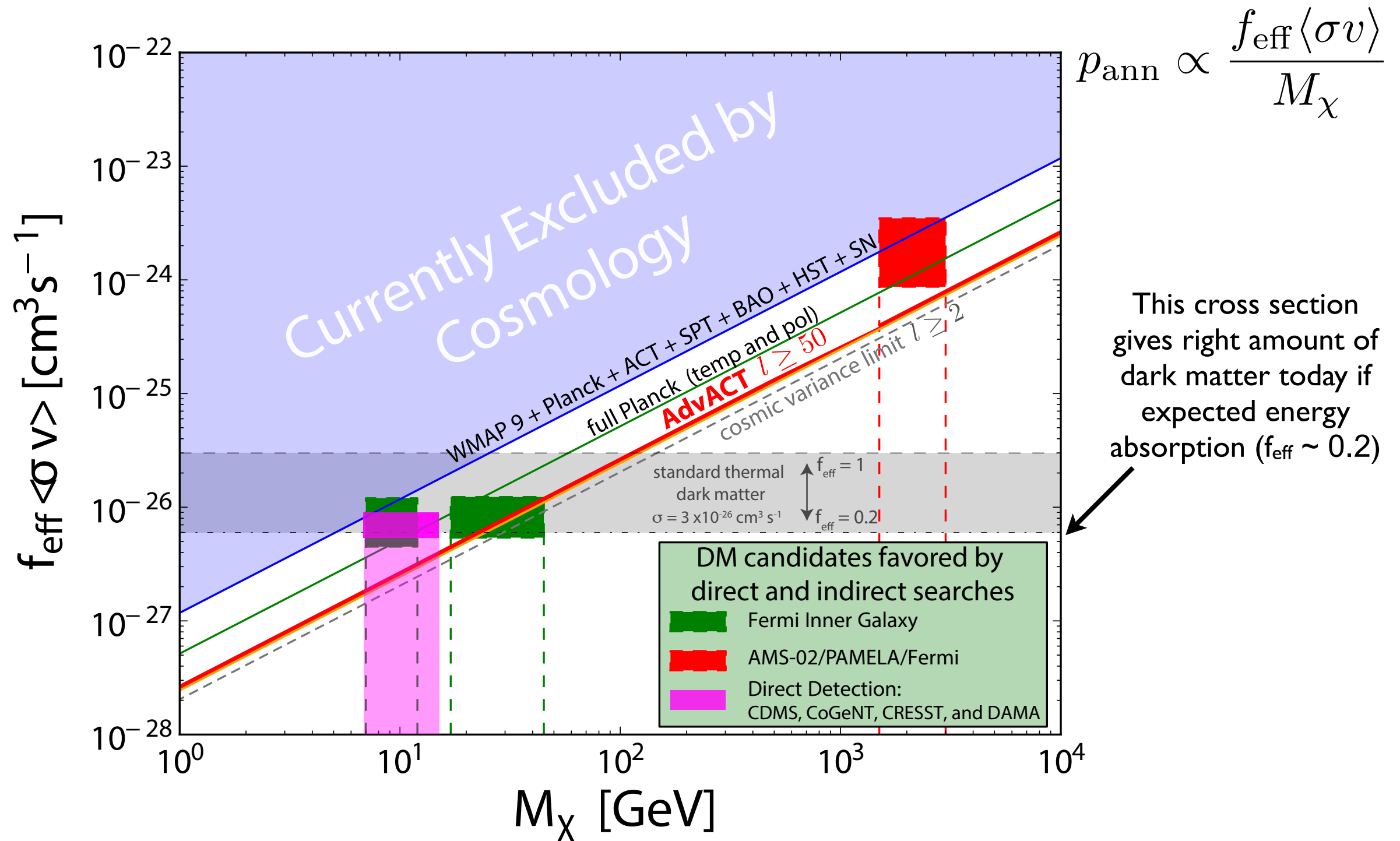
β_1 gives 99.9% of CMB power spectrum variance

Padmanabhan & Finkbeiner;
Slatyer, Padmanabhan, Finkbeiner;
Finkbeiner, Galli, Lin, Slatyer

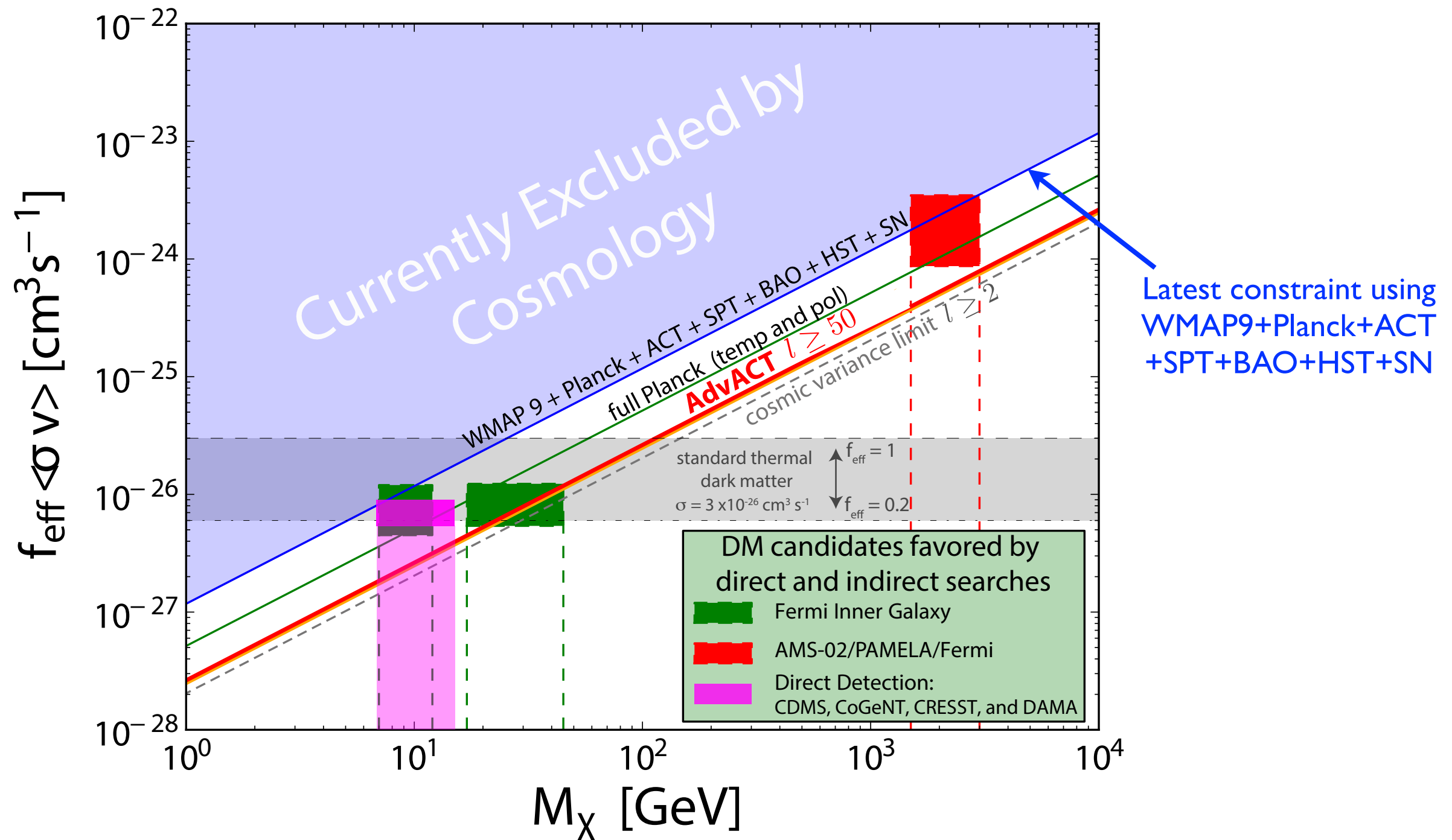
Current Constraints



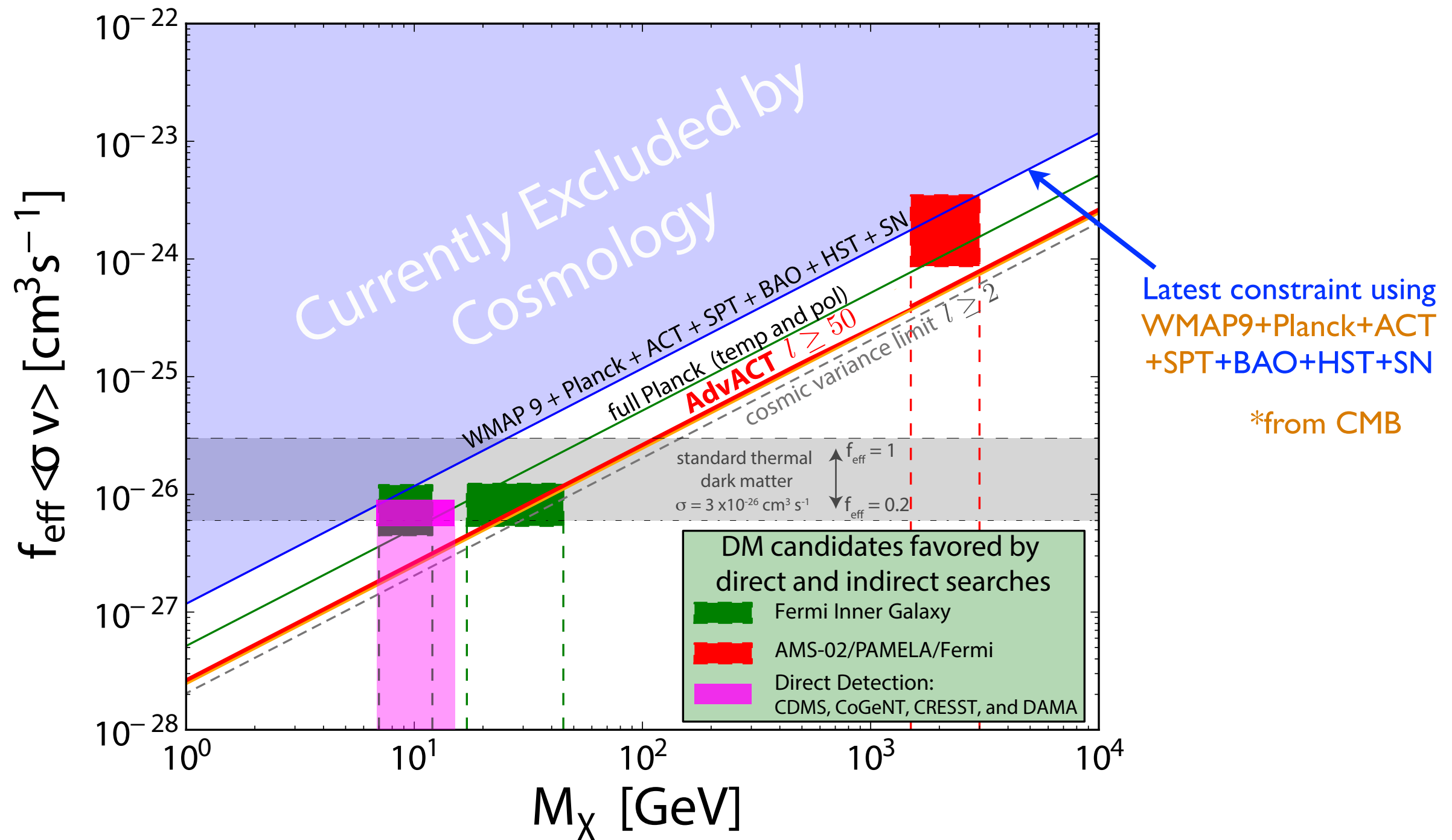
Current Constraints



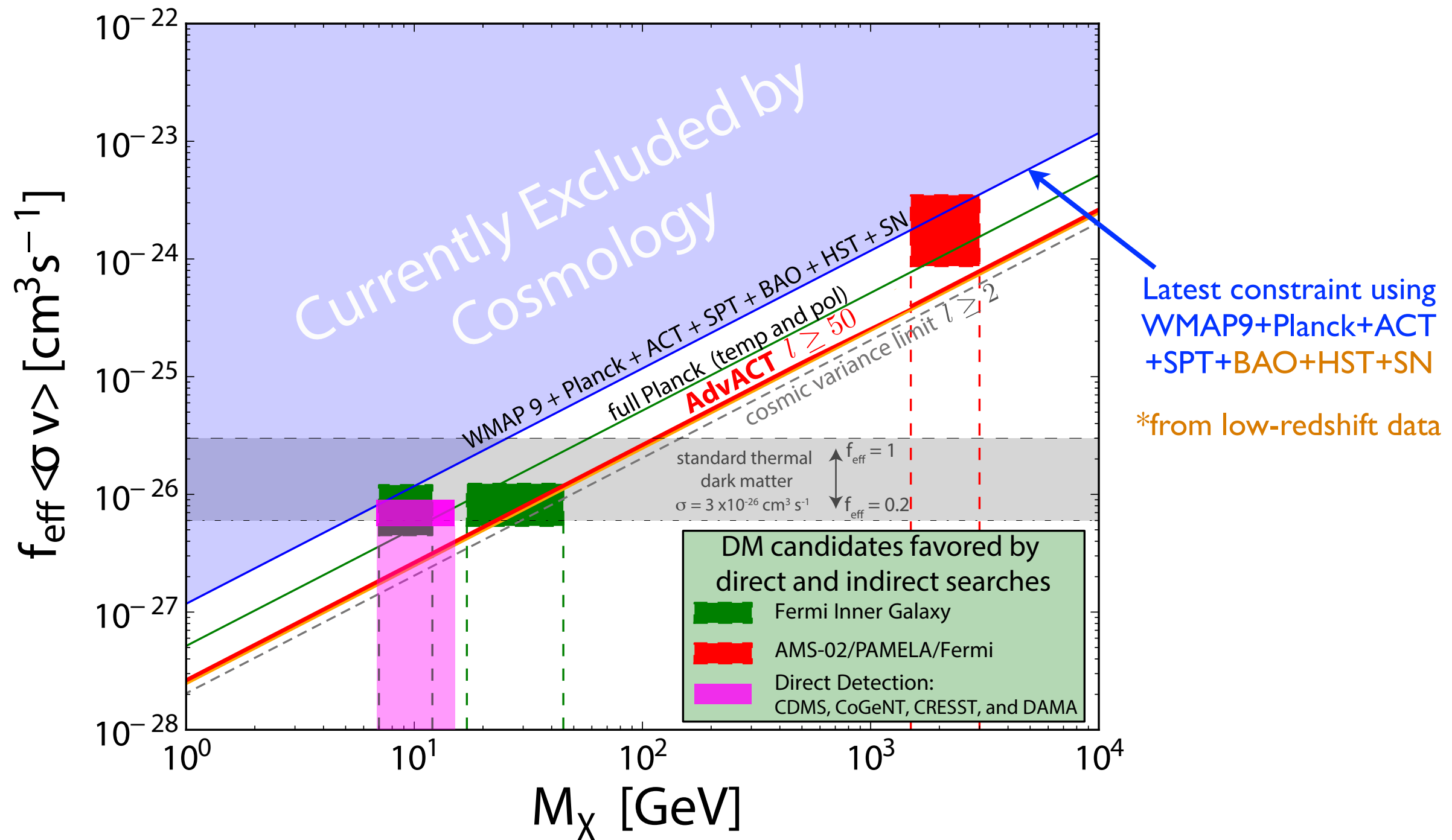
Current Constraints



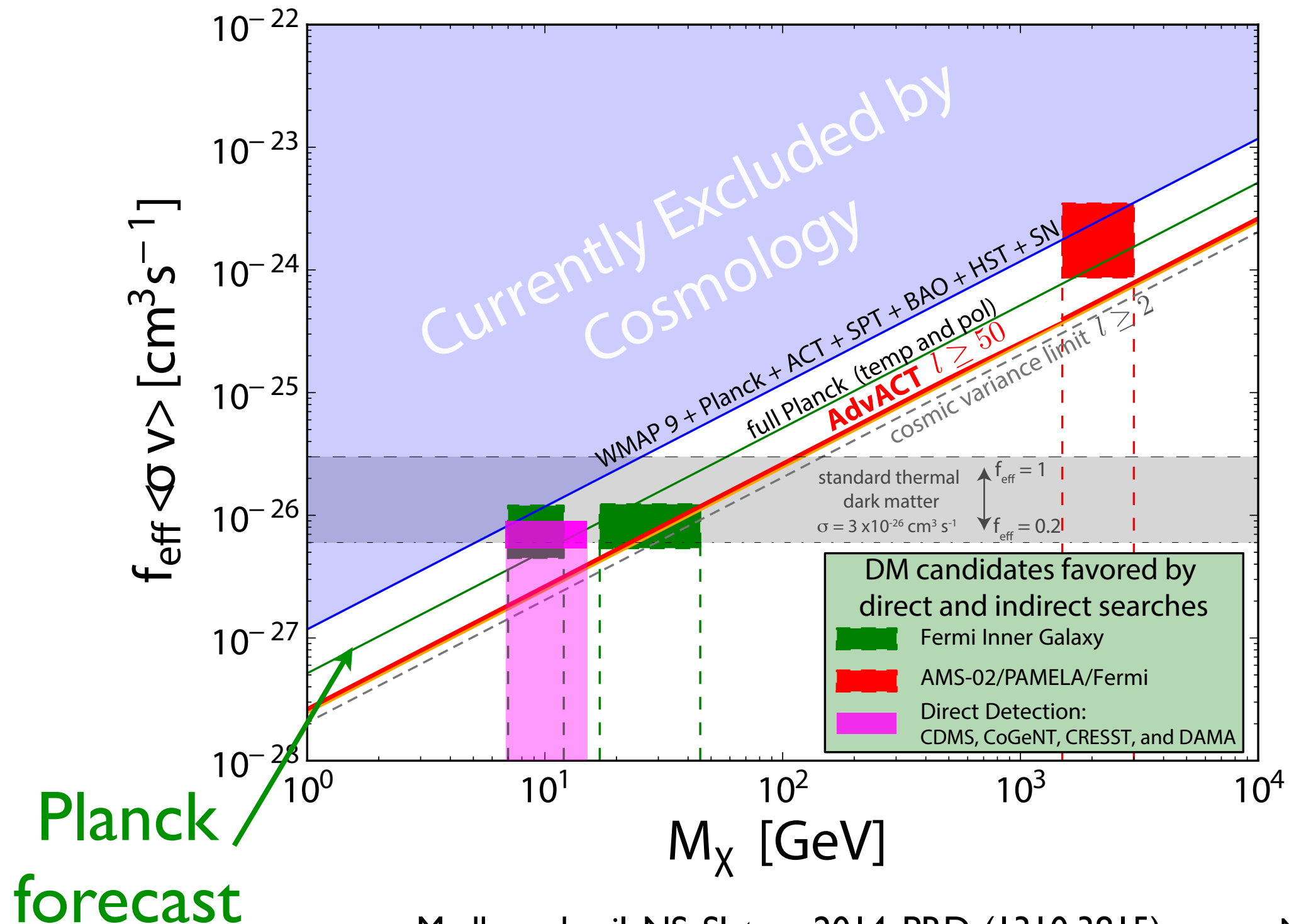
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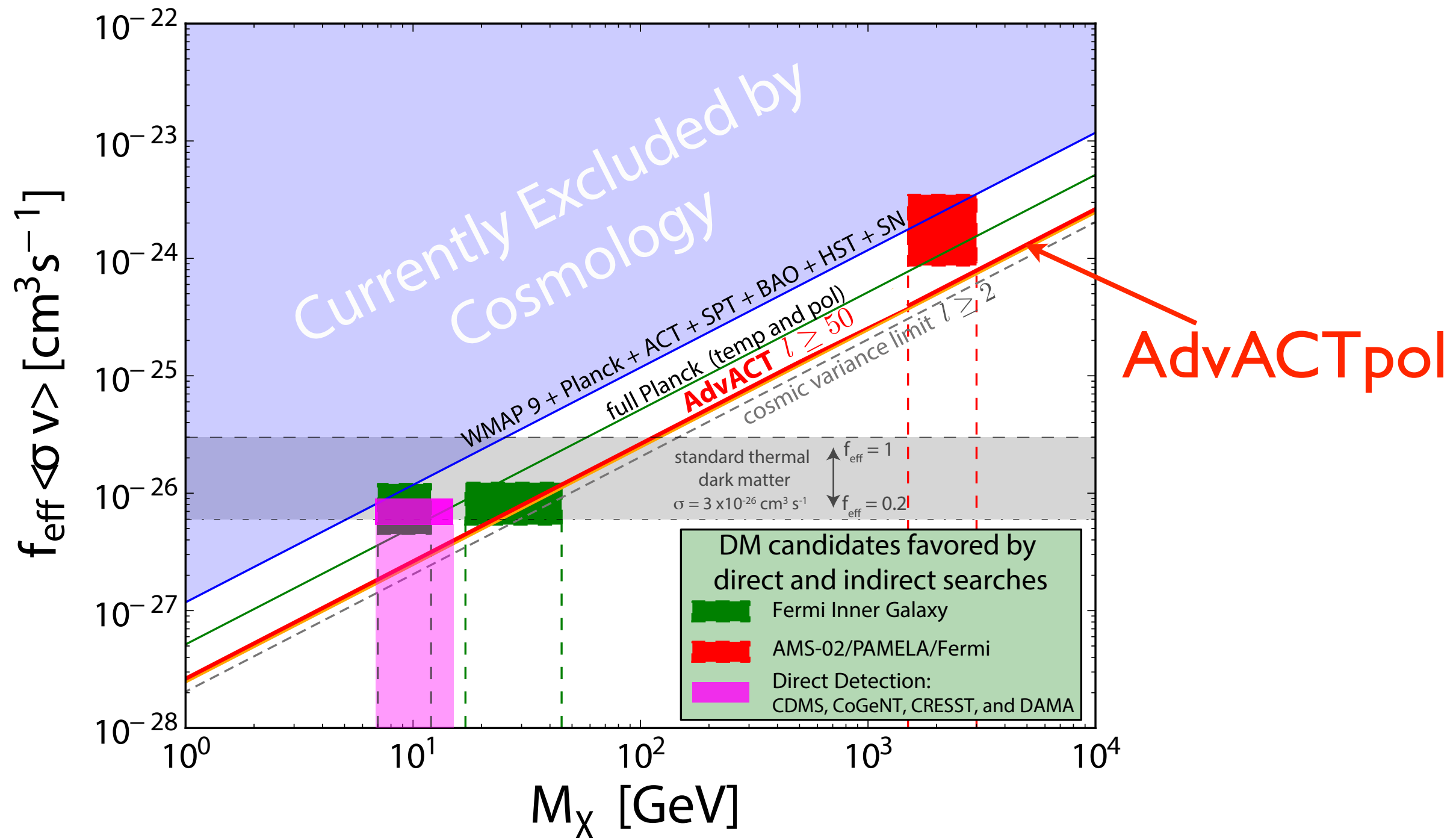
Current Constraints



Current Constraints



Current Constraints

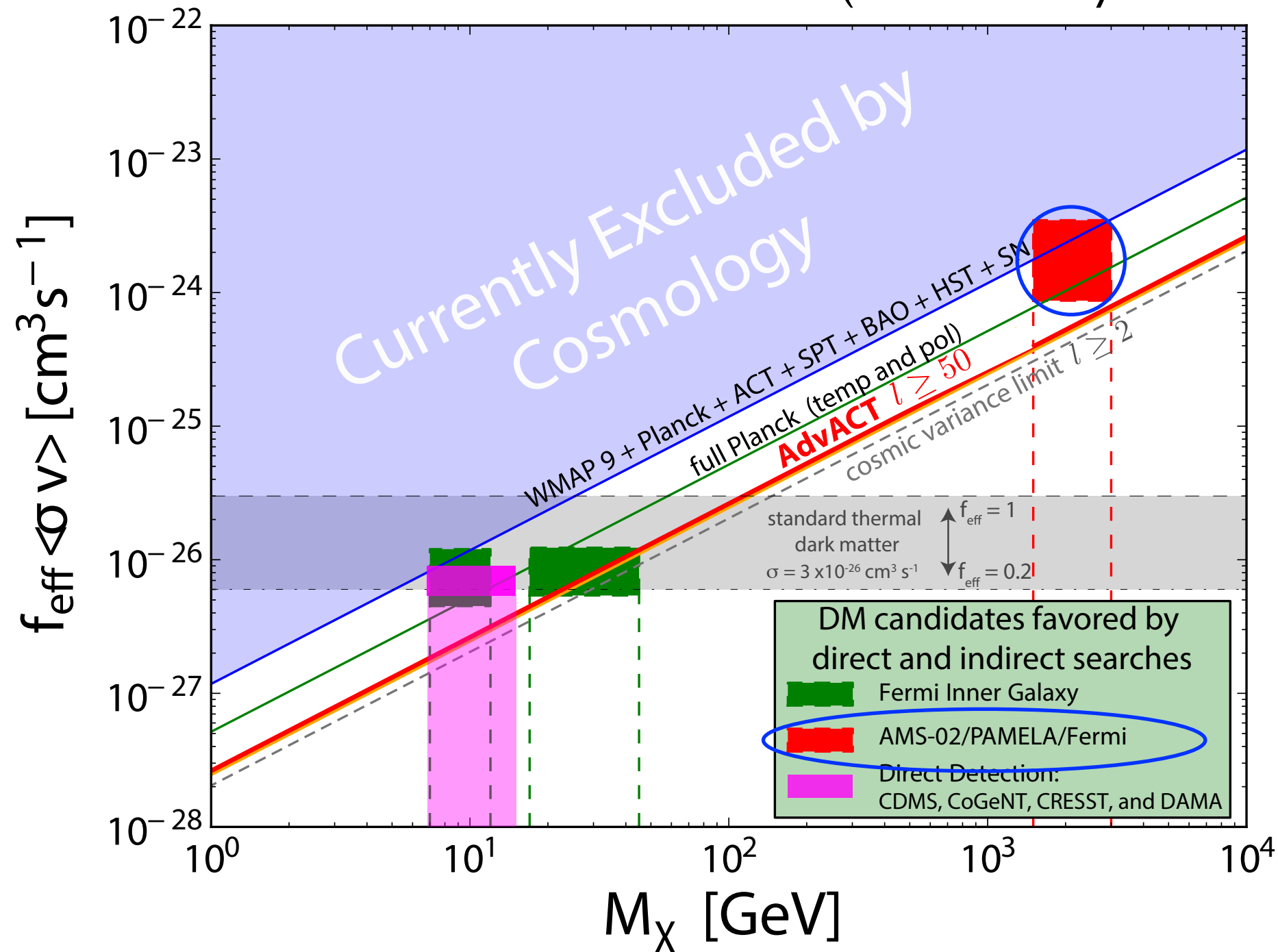


PAMELA/Fermi/AMS-02

e.g. $\text{DM} + \text{DM} \rightarrow A'A', \quad A' \rightarrow e^+e^-, \mu^+\mu^-, \pi^+\pi^-$

Arkani-Hamed et.al., Pospelov & Ritz

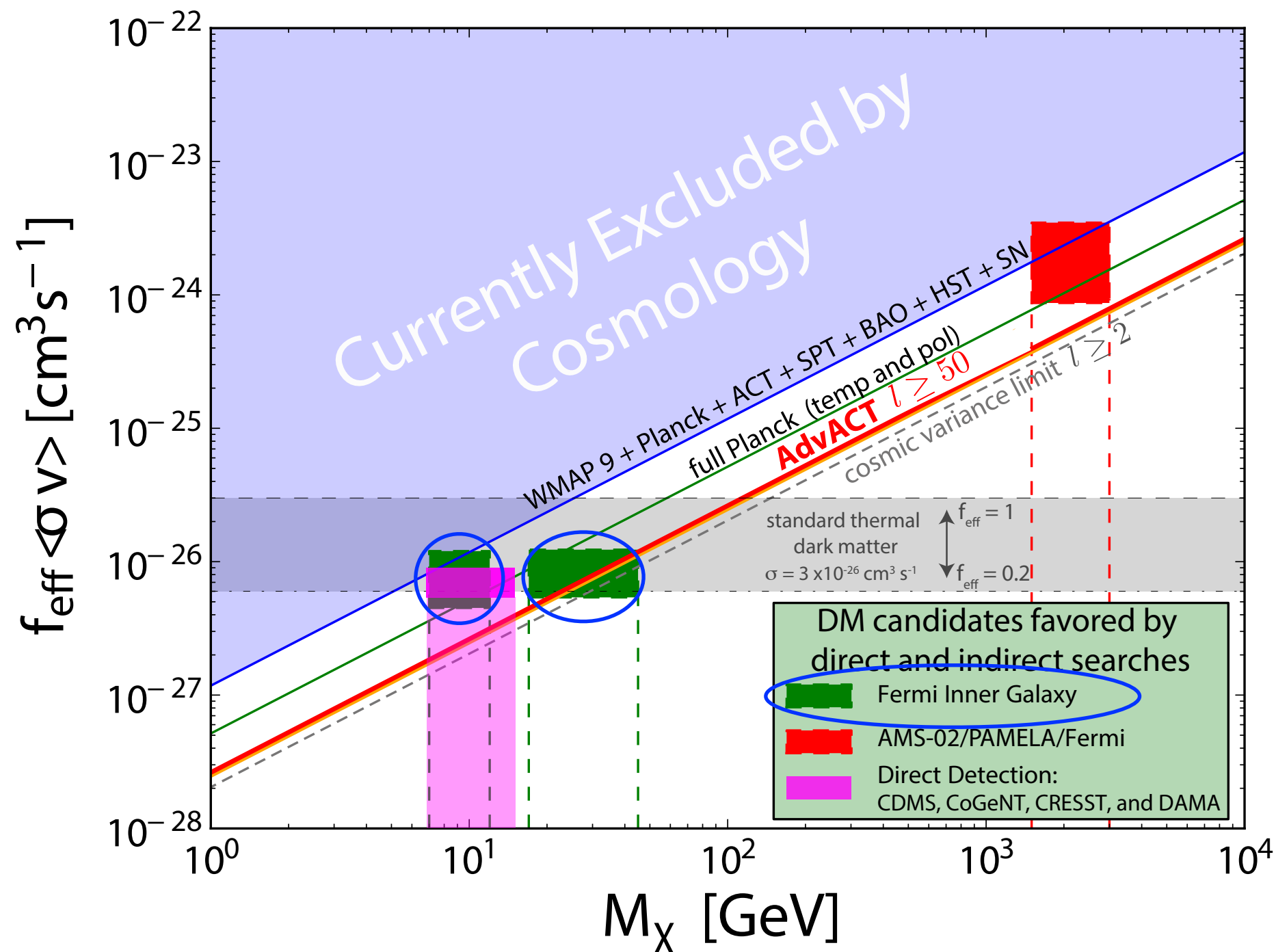
(based on fit by Cholis & Hooper, 1304.1840)



Fermi Inner Galaxy

Hooper &
various collaborators

DM + DM \rightarrow hadrons/leptons



Conclusions

- Dark matter annihilation constraints from CMB and Low-z data have been updated
- New limits are a factor of 2 better than before
- Constraints are probing interesting regimes
- Future reach of Planck and Advanced ACTpol is exciting- may find/confirm a DM signal with CMB